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MISSOURI RIVER BASIN PLANKTON STUDY: REPORT OF THE PLANKTON SURVEY MADE IN THE MISSOURI RIVER DURING JULY, AUGUST, AND SEPTEMBER 1950

Kenneth E. Damann

Environmental Health Center
Cincinnati, Ohio

August 1951

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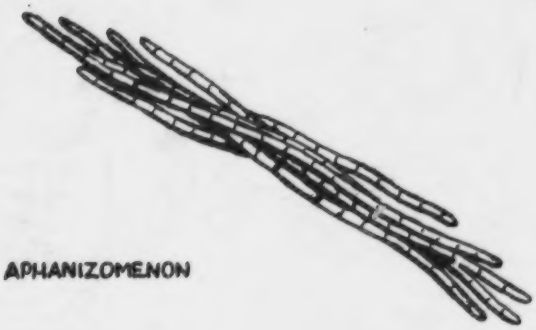

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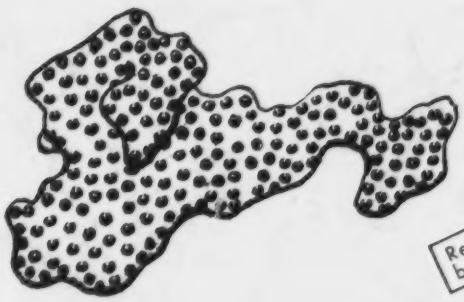

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MISSOURI RIVER BASIN PLANKTON STUDY

Report of the plankton survey made in the Missouri River Basin during July, August, and September 1950.

By

Kenneth E. Damann
Special Consultant

Conducted by the
Environmental Health Center
Cincinnati, Ohio
in cooperation with the
Division of Water Pollution Control
Missouri River Basin Office
Kansas City, Missouri

Details of illustrations in
this document may be better
studied on microfiche.

Federal Security Agency
Public Health Service
Environmental Health Center
Cincinnati, Ohio
August 1951

I

MISSOURI RIVER BASIN PLANKTON STUDY

Table of Contents

Introduction 1

Acknowledgment 2

Summary and Conclusions 3

Review of Literature 5

Area Studied 6

Methods and Materials 7
Plankton Counting Procedure 8
Sampling Schedule 8

Presentation of Plankton Data 10
Proposed Standards for Plankton Significance . . . 11
Missouri River vs. Its Tributaries 12
Three South Dakota Tributaries 15
The James River 15
The Vermillion River 17
The Big Sioux River 19
Lake Mitchell, Mitchell, South Dakota 22
Upper Souris River Area 24
Lake Darling 24
The Des Lacs Lakes 24
The Little Missouri River 25
The Yellowstone River 27
Fort Peck Reservoir 29
The Platte River Basin 34
The North Platte River 34
Lake McConaughy vs. Guernsey Reservoir 35
The Platte River 38
The South Platte River 38

The Kansas River Basin 39
Enders Reservoir 39
Kanapolis Reservoir 39
Holton Reservoir 42
Horton Reservoir 42
Reservoir Plankton vs. Stream Plankton 42

Presentation of Chemical Data 43
Iowa State Hygienic Laboratory Results 45
Missouri River, July 1950 - January 1951 45
Turbidity 45
Nitrogen and Phosphorus 45
United States Geological Survey Results 46
Missouri River, October 1950 - January 1951 . . . 46
Turbidity 46
Nitrogen and Phosphorus 47
Reservoirs vs. Rivers 49
Nebraska State Health Department Results 51
The Platte River 51
Water Temperature 51

Discussion 54

Literature Cited 55

Appendixes
A. List of Plankton Samples Collected in the Missouri River Basin Survey 57

B. List of Master's Degree Thesis Titles Completed on Limnological Problems at Kansas State Teachers College, Pittsburg, Kansas . . . 70

C. Chemical Analyses of Fort Peck Reservoir Water During August, 1948 71

D. Chemical Analyses Completed on Missouri River by the State Hygienic Laboratory, Iowa City, Iowa. 73

E. Chemical Analyses Completed by United States Geological Survey Laboratory 78

F. Chemical Analyses Completed by Nebraska State Department of Health Laboratories 87

List of Figures

No.	Title	Following Page
1	Mobile Laboratory, Tow Car, and Boat	7
2	Plankton Populations Recorded in the Missouri River Basin during July, August and September 1950.	12
3	Plankton Populations of the Missouri River vs. Populations Occurring in Tributaries.	14
4	Seasonal Periodicity of Plankton in Lake Michigan at Chicago, Illinois	32

List of Tables

No.	Title	Page
1	Plankton Survey of the James River between Jamestown, North Dakota and Yankton, South Dakota, during July 1950.	16
2	Plankton Survey of the Vermillion River between Route 16 West of Sioux Falls and Vermillion, South Dakota, during July 1950.	18
3	Plankton Survey of the Big Sioux River between Sioux Falls, South Dakota and Sioux City, Iowa, during July 1950.	20
4	Comparative Flow Rates on Three South Dakota Tributaries Expressed as Cubic Feet per Second from October 1948 through September 1949.	21
5.	Plankton Sampling on Lake Mitchell, Mitchell, South Dakota, during a Blue-green Algal Bloom on July 16, 17 and 18, 1950.	23
6	Plankton Survey of the Des Lacs Lakes on July 24, 1950	26
7	Plankton Survey of the Yellowstone River from July 31 through August 6, 1950.	28
8	Fort Peck Reservoir Plankton Samples - August 2, 1950.	30
9	Summary of Plankton Samples Collected by Corps of Engineers on Fort Peck Reservoir, August 10-14, 1950.	31

List of Tables (Continued)

No.	Title	Page
10	Summary of Nitrates Found Occurring in Fort Peck Reservoir during August 1948.	33
11	Plankton Survey of the North Platte River between Pathfinder Reservoir, Wyoming and the Missouri River.	36
12	Plankton Survey of the Guernsey Reservoir and Lake McConaughy on the North Platte River in Wyoming and Nebraska.	37
13	Plankton Survey of the Kanapolis Reservoir on the Smoky Hill River, August 20, 1950.	41
14	Plankton Abundance in and below the Reservoir Lakes in the Missouri River Basin during August, 1950.	44
15	Plankton Abundance in Reservoirs where Samples were not Available Below the Impoundment for Comparative Purposes as in Table 14.	44
16	Chemical analyses of the Missouri River and Two Tributaries between Nebraska City, Nebraska, and Toston, Montana, during January 1951.	48
17	Summary of Chemical Analyses Completed by the United States Geological Survey in the Missouri River Basin during October 1950.	50
18	Summary of Chemical Analyses of the Platte River Completed by the Nebraska State Health Department during August 14 through 18, 1950.	52
19	Summary of Chemical Analyses of the Missouri River at four Stations and of the Platte River at Ashland, Nebraska, on or about August 15, 1950.	52
20	The Maxima and Minima Nitrogen and Phosphate Concentrations in PPM Reported by the Nebraska State Health Department for the Platte River from June through August, 1950.	53

INTRODUCTION

The Missouri River Basin Development Plan, as approved by the Congress of the United States in the Flood Control Act of 1944, envisions the construction of more than 100 dams and reservoirs in the Missouri River Basin. At least 30 are already completed or in advanced stages of construction.

The reservoirs have a multiple purpose, with the control of flood waters being one of the most important features. Stored waters can be utilized for irrigation, production of hydroelectric power, creation of recreational facilities, fish and wildlife production, municipal water supply sources, and silt detention. With each impoundment of natural waters in any geographical area, it is entirely possible that biological problems new to the area may develop. The need for a study of biological problems associated with or arising from the impoundment program in the Missouri River Basin was discussed with the Basin States during fiscal year 1948 and at the Missouri Basin Health Council Meeting on August 13, 1948. Subsequent discussions between representatives of the Environmental Health Center and the Missouri Drainage Basin Office led to a presentation of the general problem to the Environmental Health Center. Considerable correspondence and consultation followed between the offices of the Public Health Service and other State and Federal agencies affected by such a study, before an outline of the proposed method of approach to the problem was eventually submitted to the Missouri River Basin Office for approval, in a letter dated March 29, 1950. A reconnaissance survey, to be made under the direction of the Environmental Health Center with the co-operation of the Missouri River Basin Office, the Corps of Engineers, and other State and Federal agencies, was agreed upon.

The prime objectives of this survey were: to determine plankton population in various areas of the Missouri River Basin during the summer months; to learn something of the physical, chemical and biological conditions of importance to plankton production and distribution during this period; to define problem areas; to gain an over-all picture of ecological conditions affecting algal growth in the Basin; and to observe the effects of impoundment upon plankton production wherever reservoirs were already in operation in the Basin.

The term "plankton" in this report has been used in a general way to include all of the microscopic organisms, exclusive of the bacteria, which were found free-floating in aquatic habitats. Typical euplankton, tychoplankton and periphyton species are not recognized as such but are included as a part of the total plankton wherever encountered.

ACKNOWLEDGEMENT

The completion of this field survey covering most of the Missouri River Basin in the short interval of two months resulted only because of the close cooperation rendered by various State and Federal agencies located in the area studied.

The success of the study is due in large part to the wholehearted cooperation of Federal and State groups within the basin. Special mention should be made of the plankton and chemical samples taken by the Corps of Engineers, Missouri River Division, Omaha, Nebraska, the U. S. Geological Survey, the Bureau of Reclamation, Region 6, Billings, Montana and Region 7, Denver, Colorado, their field officers within the basin and the State Health Departments. The State Hygienic Laboratory, Iowa City, Iowa, the U. S. Geological Survey, Lincoln, Nebraska, and the Nebraska State Department of Health made the chemical analyses. Special recognition can be found in the body of the report concerning contributions made by several individuals. To make this list complete would mean mentioning the personnel of the State health departments, Bureau of Reclamation, Corps of Engineers, and municipal water plants contacted, as they all contributed generously of both time and energy in activities related to this study. Since such action is not practicable nor possible, the writer wishes, at this point, to gratefully acknowledge personally the interest with which he was received and the courteous consideration given by all individuals concerned.

Contributing Agencies

State Health Departments:

Colorado	Nebraska
Iowa	North Dakota
Kansas	South Dakota
Missouri	Wyoming
Montana	

Bureau of Reclamation
Region 6, Billings, Montana

Bureau of Reclamation
Region 7, Denver, Colorado

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SUMMARY AND CONCLUSIONS

1. A plankton reconnaissance was made in the Missouri River Basin during the summer of 1950. The total distance covered was over 6,000 miles extending along the Missouri River, its tributaries, and associated waters in Missouri, Kansas, Nebraska, Iowa, South Dakota, North Dakota, Montana, and Wyoming.

2. Chemical sampling in various parts of the Missouri River Basin was carried on through the co-operation of the Nebraska State Health Department, Iowa State Health Department, Geological Survey, Surface Water Division, Lincoln, Nebraska, and the Corps of Engineers. Permanent sampling stations were established and visited regularly in some instances for a full year. A portion of the data collected has been included as Appendices C, D, E, and F.

3. Plankton productivity in the Missouri River was found to be very low as compared to its tributaries. An average population of 460 organisms per ml was recorded for 27 points of collection between St. Louis, Missouri, and Fort Peck Reservoir in Montana. The maximum plankton population was 2400 organisms per ml and was found just below the mouth of the Vermillion River at Vermillion, South Dakota, on July 12. The minimum population of 20 organisms per ml occurred at Ft. Randall in South Dakota during the same week in July. Nineteen tributaries, in the same area as mentioned above, were found to contribute an average of over 7,000 organisms per ml to the Missouri River. The maximum count of 64,520 was found in the Vermillion River, the source that undoubtedly was responsible for the maximum found in the Missouri River. Minimum populations of 140 organisms per ml were found in both the Gasconade River and the Mississippi in Missouri.

4. Plankters contributed to the Missouri River by tributaries apparently were subjected to adverse conditions of high turbidity and rapid current and did not multiply. Completion of dams in strategic areas could conceivably decrease current velocity and turbidity sufficiently to permit survival and multiplication of plankton organisms, either in or below the reservoirs.

5. The most productive tributaries, ranked in descending order of plankton populations, were the Big Sioux, Vermillion, and the James Rivers in South Dakota, and the Platte River in Nebraska. Considerable qualitative variation was exhibited and the dominance of any one form or group was restricted to a single tributary or portion thereof. Frequently the dominant form of one tributary was completely lacking in another.

6. The maximum plankton population for the entire survey was found in the Des Lacs Lakes region north of Minot, North Dakota. The dominant organism, Aphanizomenon, was present in quantities which would total more than five miles of filament per quart of water (102,500 organisms per ml). (It should be noted that the Des Lacs area is outside of the Missouri River Basin, but is included in the area subject to influence by the developmental program).

7. Plankton productivity in the reservoirs sampled appeared to be considerably less than that found in streams or rivers below these reservoirs. The increase in productivity in rivers was probably due to clarification and nutrient enrichment brought

about by the use of the reservoir. Thus, there is a suggestion that attention should be focused on the operation of the reservoir with respect to the effect of discharge rates on the river below. Reservoirs with tributaries from arid or nonagricultural lands were noted to have the lowest plankton densities.

8. Plankton densities were found to increase progressively with the distance downstream in several tributaries of the Missouri River. The Platte River plankton populations during September revealed the most convincing trend with an increase from less than 2,000 to more than 30,000 organisms per ml over a distance of approximately 300 miles. Total phosphorus (expressed in terms of PO_4) was noted to increase from 1.30 ppm to 3.96 ppm over the same distance in August. Thus, the effect of the added enrichment from the drainage basin in the agricultural area would seem to be responsible for at least a portion of this trend.

9. Nutrient enrichment, as expressed by nitrogen and phosphorus concentrations, was evident in the Missouri River. During November, 1950, the total phosphorus (PO_4) was noted to increase from 0.558 ppm at Pierre, South Dakota, to 9.56 ppm at Nebraska City, Nebraska, a distance of approximately 600 miles. A maximum of 16.6 ppm of total phosphorus (PO_4) was reported at Council Bluffs, Iowa, on the Missouri River on October 14, 1950. Therefore, the lack of essential minerals does not appear to be the answer to the low plankton productivity. The high turbidities plus the high current velocities characteristic of the Missouri River seem to be operating as the limiting factors. With the completion of the Fort Randall Dam above Yankton, South Dakota, the turbidity and high current velocity will be reduced in this area. Theoretically, therefore, the plankton populations that are currently being introduced via the James, Vermillion, Big Sioux, and Platte Rivers should survive and multiply in the Missouri River.

10. A procedure for interpreting the significance of the quantity of plankton found in a water supply with relation to its potential seasonal quality has been presented (page 11). Such a scheme is not intended to be applicable to all areas of the United States. It was developed as a means of making relative comparisons of the plankton populations found during the summer season in the Missouri River Basin only.

REVIEW OF LITERATURE

Numerous lakes throughout the length and breadth of the United States have been subjected to extensive biological investigations during the past fifty years. During the same period, comparatively little attention has been given to studying the biology of the major rivers. However, a few notable exceptions are represented in the contributions made by Allen (1920) on the San Joaquin River in California, by Kofoid (1908) on the Illinois River, by Wiebe (1930) on the Mississippi River, and by Purdy (1923) on the Ohio River.

At the time this field study was being conducted there were no specific published references encountered relative to plankton of the Missouri River. More recently, Berner (1951) published data from a portion of a master's thesis (Berner, 1947) on the limnology of the Missouri River from its mouth to the Iowa State Line. The study was completed during the summer of 1945.

Brinley (1950) made plankton collections from 18 lakes and streams in the Rocky Mountain National Park in Colorado between June 13 and July 22, 1949. He noted that plankton populations were extremely low in the mountain lakes and streams as compared to surface waters in Ohio. This paucity of plankton appeared to be directly correlated with the lack of decomposed organic matter in the mountain streams. Predominate organisms were diatoms with Asterionella usually the most abundant genus.

Neel (1951), Biologist of the Missouri River Basin, has reported on limnological studies conducted on the North Platte River during July, August, October, and November, 1950, as part of a water pollution investigation conducted by the Public Health Service for the North Platte River Basin. Specific references will be made later to these data.

Species lists of the algae in the Devils Lake area of North Dakota were compiled by Moore (1917), Moore and Carter (1923) and Taft (1948). Similar lists for the Medicine Bow area of Wyoming have been published by Giles (1934) and Miller (1936). No attempt has been made to compile all references of this nature, but those encountered in reviewing the literature have been listed.

There have been several reports on various phases of the biology of the Devils Lake region of North Dakota beginning with Pope (1908). Moberg (1918) studied the variation in horizontal distribution of plankton while participating with Young in a study of the life of Devils Lake. Young (1924) presented data on the seasonal periodicity of the algae, protozoa, rotifers, and crustaceans in the alkaline lakes of the Devils Lake area.

The salt concentration was found to increase with decreasing lake level from 8,471 ppm in 1899 to 15,210 ppm in 1923. These waters are hardly comparable to the Missouri River or its tributaries.

The most comprehensive study of annual limnological cycles yet attempted in any part of the Missouri River Basin is represented by the work of Ponnak (1949). Seven reservoir lakes, all located within a radius of 15 miles of Boulder, Colorado, were studied on a year-round basis. The chemical, physical, and plankton cycles for each lake were established and compared from samples collected about once a month throughout a continuous year.

Tiemeier (1951) spent the period June 15 - August 31, 1950, at Kanapolis Reservoir on the Smoky Hill River near Saline, Kansas, studying the limnological aspects of the area relative to good reservoir management. The reservoir water level was noted to fluctuate 30 feet during this period indicating problems to be encountered in controlling mud flats and establishing rooted aquatics. Phytoplankton was predominantly blue-green algae and was noted to increase with rise in water level.

Letters of inquiry requesting information concerning limnological studies completed and the existence of taste and odor problems in local water supplies were addressed to all colleges in the Missouri River Basin. T. M. Sperry, Kansas State Teachers College, Pittsburgh, Kansas, submitted a list of nine master's degree theses concerning limnological problems. He indicated that these studies (listed in Appendix B) represent the only fresh-water biological work done in southeastern Kansas. All other replies to the inquiry failed to yield any specific information on items other than reference to publications which have been noted above.

AREA STUDIED

The Missouri River Basin is one of the ten river basin areas of the United States that have been designated by the U. S. Public Health Service as working units for purposes of the Water Pollution Control Law (Fig. 2). The official headquarters of the Basin are maintained at Kansas City, Missouri. It was through the cooperation of this office that the details of the survey relative to field activities were planned and efficiently executed by Ralph Porges, Sr. Sanitary Engineer, In Charge of Field Staff.

The Missouri River originates at Three Forks, Montana, in the extreme western part of the state, where the Gallatin, Madison, and Jefferson Rivers combine. From this point, it

flows approximately 2,500 miles through the States of Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas, and Missouri (Fig. 2). It carries an average of 45,000,000 acre-feet of water annually into the Mississippi River at St. Louis, Missouri. The average flow at Hermann, Missouri, 99 miles above St. Louis, is over 50,000 cfs.[1]

The principal tributaries of the Missouri River are the Yellowstone, Platte, and Kansas Rivers. The latter river drains the basins of the Smoky Hill, Saline, Solomon, Republican, and Big Blue Rivers. However, collections were not restricted to these sources since most tributaries and reservoirs were sampled as encountered regardless of size or state of construction.

METHODS AND MATERIALS

The Environmental Health Center, Cincinnati, Ohio, provided an automobile, boat, motor, microscope, and plankton sampling devices. The writer converted a small house trailer into a mobile laboratory which made it possible to collect and examine samples without leaving the immediate area (Fig. 1). The trailer was equipped with a Foerst electric centrifuge, a Bausch and Lomb binocular compound microscope, and all other incidentals necessary to make complete quantitative and qualitative plankton examinations. A small reference library along with all of the other necessary equipment permanently in place proved to be a time saver as well as a convenience in moving from place to place over such a wide area. Municipal water purification plants were used as temporary headquarters whenever possible as the personnel of water treatment plants was directly interested in this study.

Over 6,000 miles were traveled in the Missouri River Basin between June 29 and August 26, 1950. Approximately 300 samples were collected in the states of Missouri, Kansas, Nebraska, Iowa, South Dakota, North Dakota, Montana, and Wyoming. As the sole individual in the survey party, it was necessary for the author to do all of the driving in transporting the mobile laboratory, sampling and collecting of field data, packing of field equipment, launchings of the boat, and microscopic examinations. As a result, samples were collected at various hours from 6:00 A.M. to 12:00 midnight. Because it was desirable to analyze samples as soon after collection as possible, microscopic examinations were made at practically any hour of the day and night.

The immediate availability of a light car-top boat and 2-1/2 H.P. motor proved most useful in collecting from a wide

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[1] LeBosquet Jr., M. 1943. Winter discharge necessary for pollution control between Fort Randall near Yankton, South Dakota, and the mouth. Environmental Health Center, Missouri River Investigation Report.

Fig. 1. Mobile Laboratory, Tow Car, and Boat.

variety of habitats. Plankton tow nets (Wisconsin standard and Clarke-Bumpus) equipped with No. 25 bolting silk were used for horizontal sampling. A Kemmerer sampler was used for depth samples. Vertical water temperatures were measured with a maximum-minimum thermometer (Sixes type) and pH with a Rascher-Betzold colorimetric portable kit. A Secchi disk was used to determine depth of light penetration.

Plankton Counting Procedure

Samples of at least one liter were collected for quantitative analyses, while plankton tow nets were used to concentrate organisms in larger volumes of water for qualitative determinations. Microscopic examinations were made immediately following collection wherever possible and the total number of organisms per ml determined by the Direct Count method (Damann, 1950). With this method the sample is not concentrated in any way but examined in the original state in a Sedgwick-Rafter counting cell. A 10X ocular with an 8 mm, 21X objective proved to be the most useful combination for field counting. (See page 11).

Following Direct Count determinations, a portion of each sample was concentrated with the Foerst electric centrifuge and preserved for further quantitative determinations. The tow net collections, likewise, were preserved in 4% formalin. A complete list of organisms encountered is in preparation.

Throughout this report, all quantitative plankton results are expressed as total number of organisms per milliliter according to the following definition. Such forms as occur in clusters or colonies that are easily broken apart are counted as one organism for each cell. This group includes Asterionella, Tabellaria, Dinobryon, Fragilaria, Synedra, and others of a similar organization. Irregular colonies like those produced by Microcystis, Sphaerocystis, Tetraspora, Merismopedia, etc., have been enumerated, with the number of organisms being equivalent to the number of areal units (1 unit = 20 microns x 20 microns). Other forms that occur in definite filaments, such as Melosira, Oscillatoria, Aphanizomenon, etc., have been counted as one organism being the equivalent to each 100 microns of length.

Sampling Schedule

The first official sample was taken from the Missouri River at Kansas City, Missouri, Municipal Water Plant intake on June 29, 1950. The survey then proceeded to Lawrence, Topeka, Holton, and Horton, Kansas, in that order, before returning to the Missouri River at Rulo, Nebraska. The week of July 8 was spent exploring the Big Sioux, Vermillion and James Rivers in South

Dakota where extremely high plankton populations were encountered. Thenceforth, to the Garrison dam site in North Dakota, sampling was confined principally to the Missouri River and its tributaries.

In the vicinity of Minot, North Dakota, it was proposed to divert water from the Missouri River into the Souris River thence into the James River in South Dakota. After finding highly productive water in the James River, it was deemed advisable to sample both the Souris and James Rivers in North Dakota. However, due to lack of time, it was only through the cooperation of Jerome H. Svore, Chief Sanitary Engineer, and W. Van Heuvelen, Director of Water Pollution Control of the State of North Dakota, that sampling was completed on the James River at Jamestown and on the Sheyenne and Red Rivers in the northeast portion of North Dakota. This collecting was done while the writer was working at Lake Darling and Des Lacs Lakes in the Upper Souris region of northwestern North Dakota.

Sampling was resumed on the Missouri River at Williston, North Dakota, and continued on it and its tributaries as far north as Fort Peck Reservoir in central Montana. Again, owing to lack of time and the immense size of the reservoir, it was possible to sample only in the immediate vicinity of the dam. It was through the courtesy of Carter V. Johnson, Head of Field Investigations, Corps of Engineers at Fort Peck, that a series of 25 samples was collected over a distance of more than 100 miles on Fort Peck Reservoir.

After leaving Fort Peck Reservoir, sampling was continued south on the Yellowstone River as far as Miles City, Montana. Thereafter, emphasis was placed on reservoir collecting with the following being sampled in the order mentioned:

Reservoir	Location	Source Water
1. Belle Fourche	Belle Fourche, So. Dakota	Belle Fourche River
2. Deerfield	Deerfield, So. Dakota	Castle Creek
3. Angostura	Hot Springs, So. Dakota	Cheyenne River
4. Guernsey	Guernsey, Wyoming	North Platte River
5. LaPrele	Douglas, Wyoming	LaPrele Creek
6. Lake McConaughy	Ogallala, Nebraska	North Platte River
7. Enders	Enders, Nebraska	Frenchman Creek
8. Kanapolis	Ellsworth, Kansas	Smoky Hill River
9. Holton	Holton, Kansas	Straight Creek
10. Mission Lake	Horton, Kansas	Mission Creek

The Solomon, Big Creek, Smoky Hill, Saline, and Republican Rivers were sampled enroute across Kansas to the Kanapolis Reservoir. Due to heavy rains in the area, these rivers were all at flood stage and hardly characteristic of conditions that ordinarily prevail in late August and September.

The State of Nebraska Department of Health had instituted their own plankton study program under the direction of L. O. Vose, Head of the Department of Health Laboratories. Hence, the only collecting done in Nebraska by the writer was along the extreme eastern border on the Missouri River and at one station on the Platte River near Fremont, Nebraska. In the western part of the state, the North Platte was sampled enroute to Lake McConaughy and the South Platte enroute to Enders Reservoir. Thus, the field collecting of the writer excluded the main portion of the Platte River across Nebraska. Through the assistance of Allan E. Johnson, who was in charge of the plankton work for the Nebraska State Health Department, this void was filled by a collection of 15 samples in September which were submitted to the writer for examination.

In Wyoming, the North Platte River was sampled above and below Guernsey Reservoir. Plankton populations for both Pathfinder and Alcova Reservoirs were determined by the writer from samples collected by J.K. Neel, Biologist for the Missouri River Basin. It was possible only by such cooperation to have rather uniform sampling on the Platte River from its mouth to near its point of confluence with the Missouri River, which represents a distance of over 700 miles.

The portion of the Missouri River and its tributaries betwenn Kansas City and St. Louis, Missouri, was sampled on August 25 and 26, 1950. The entire area covered in the Missouri River Basin, with most of the sampling points represented, is illustrated in Fig. 2. The complete itinerary for the survey is represented in Appendix A, with all of the samples listed and dated in the order they were collected.

PRESENTATION OF PLANKTON DATA

Any attempt to present a biological picture, relative to plankton organisms, of a drainage basin covering 529,350 square miles during a period of two months is very apt to result in some under-exposures. It should be understood that such an objective was not within the province of this study. Rather, it was purely an exploratory survey covering as much of the Missouri River Basin as was possible in a short interval of time. Emphasis was placed upon the apparent effects of impoundments on biological productivity of the waters in the area covered. It was hoped that such a survey would focus attention on possible problem areas where more extensive annual studies could be carried out in the future.

The lack of any well defined standards relative to the quantitative consideration given to individual species of organisms by the various accepted counting methods has resulted in a condition where it is almost impossible to correlate data collected by various workers. The existence of the human element is still a most important factor when it comes to determining the unit-value to be given single celled organisms versus multicellular ones or a colonial versus a filamentous species. Most often this information is known only to the counter or author and, unfortunately, is usually not a part of the final published report. This paper has not improved the situation but it does serve to recognize the need for more refined standardization of quantitative plankton species counting procedures.

The method used in processing individual water samples was not actually selected until after considerable experimentation with the Missouri River water at Kansas City, Missouri, during the first week in the field. The rapid current velocity plus the high turbidity characteristic of the Missouri River made the plankton tow net a very impractical tool. Likewise, repeated concentrations made with the Foerst Electric Centrifuge yielded catches that were almost impossible to analyze microscopically until they had been diluted back to the original or unconcentrated state. Since at least consistency of method was desirable, the Direct Count was made the official method for the survey with both tow net and centrifuge samples taken as supplementary whenever practicable or possible.

The Direct Count originated with Baylis in the Municipal Water Plant of Baltimore, Maryland. The writer used the method for three years while working with Baylis in the Chicago Water Filtration Plant. Comparative counts were made on water of varied plankton concentrations by the Sedgwick-Rafter Method, the Foerst Centrifuge, and the Direct Count and in each instance the counts compared favorably and indicated that the Direct Count gave results equal to either of the procedures recommended by Standard Methods (Dawson, 1950).

A Procedure for Interpreting Plankton Significance

One of the most important ways in which the plankton organisms are significant is the fact that they are associated with production of tastes and odors in water supplies. The chart on page 11A developed by the writer represents a procedure for interpreting the quantity of plankton found in the Missouri River basin during July, August and September, 1950, in terms of taste and odor problems.

A procedure for Interpreting the Significance of the Quantity of Plankton found in the Missouri River Basin During July, August and September 1950.

Symbols Used in Figure 2	Total Plankton per ml	Probable Significance*
	0 - 100	Little or no productivity. Taste and odor problems unlikely
	100 - 500	Low productive water, though potentially productive depending upon the environment or the season.
	500 - 1,000	Unpredictable water. Odor problems could develop almost at any time.
	1,000 - 5,000	Odor problems are very likely to occur with the presence of specific organisms in the population.
	5,000 - 10,000	Odor problem water requiring the strictest control at all times. Carbon treatment of drinking water necessary.
	10,000 - 50,000	Highly productive water, difficult to treat satisfactorily with the most modern methods of water treatment.
	50,000 - 100,000	A biologically polluted water. Productivity extremely high. In most instances impossible to treat satisfactorily with the known methods of water purification.

* To attribute significance to a water supply on a single collection of samples is indeed hazardous. It should be recognized that the results might look quite different when expressed for the various seasons of the year. Thus, the results are indicative of the summer period only which is usually the time of most frequent algal problems (Fig. 2).

To the knowledge of the writer, there are no set standards or limitations by which the quality of water can be judged on the basis of the total number of plankton organisms present. More important is the kind or species of organisms encountered. Yet, an attempt has been made here to give significance to the quantity of plankton found in the Missouri River, its tributaries, and associated waters (see page 11A).

On the basis of the proposed standards, it appears evident that the Platte River in Nebraska, the Big Sioux, the Vermillion, and the James Rivers in South Dakota, and the Souris River region in North Dakota are definitely plankton-problem areas (Fig. 2). By the same reasoning, a large number of tributaries are likewise potential trouble makers as far as algal problems are concerned. Each such tributary system that was given special attention by sampling along its course will in turn be given individual consideration in discussions which will follow. A summary of each of the quantitative samples observed, listing point of collection, total number of organisms per ml, and the predominant organisms found comprises Appendix A.

Missouri River vs. Tributaries

The Missouri River was sampled for plankton organisms at 27 locations along the 1,700 mile stretch between St. Louis, Missouri, and Fort Peck, Montana. It was found to be relatively barren of plankton organisms at most of these points of collection. The average population of 460 organisms per ml, is quite low when contrasted with an average of 7,880 organisms per ml, for 19 tributaries. Nine of the tributaries entering the Missouri from either the north or the east side of the channel carried plankton populations averaging 14,169 organisms per ml. The ten remaining tributaries sampled, entering the Missouri from the south or the west, were found to have an average plankton population of 2,993 organisms per ml. No special significance is necessarily attached to the side of the channel from which a tributary enters.

On the whole, the tributary streams of the Missouri River were quite unpredictable. Each one produced an assemblage of organisms which marked its individualistic nature. The contention of Lackey (1943), that it is practically impossible to find two streams that are alike biologically, was well supported in the Missouri River Basin Survey.

It would also seem evident from the data in Fig. 3 that plankton organisms were not reproducing to any extent in the Missouri River proper. A maximum population of 2,400 organisms per ml was found just below the mouth of the Vermillion River in South Dakota. Most of these organisms undoubtedly were

FIGURE 8
PLANKTON POPULATIONS RECORDED IN THE MISSOURI RIVER BASIN DURING JULY, AUGUST, AND SEPTEMBER, 1950

PLANKTON POPULATIONS OF THE MISSOURI RIVER BASIN

SUMMER 1950

TOTAL PLANKTON EXPRESSED AS ORGANISMS PER ML. AS FOLLOWS:

- 0-100
- 100-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- 50,000-100,000

12 B

12 b

introduced from the Vermillion where the population was 64,520 organisms per ml (Page 14). Above the mouth of the Vermillion there were only 480 organisms per ml, 280 of which were Aphanizomenon, a form common in the James River but not found in the Vermillion at any point of collection. Repeated occurrences of this nature, where the tributary contributed a reasonably heavy population that disappeared in a very short distance, were common all the way from St. Louis, Missouri, to Fort Peck Reservoir in Montana (Figures 2 and 3).

Berner (1951) reported an average plankton population of only 67 individuals per liter during a seven month survey on the lower Missouri River. Occasional samples by Berner (1947) on a tributary stream suggested that it was serving as a diluting rather than an enriching source. He attributed the paucity of plankton in the Missouri River to the high turbidities, high current velocities, and the lack of adjoining lentic environments. Thus, the results as shown in Fig. 3 are not at all astounding when it is realized that maximum turbidities recorded by water plants at various points along the course of the Missouri River varied from 20,000 to 100,000 ppm. These turbid conditions usually persist for all but winter months when the river may be covered with ice and have minimum flow rates. High turbidities accompanied by considerable turbulence in the main stem are apparently sufficient to limit development of plankton organisms below the point where they might become producers of taste and odor problems.

The lack of adjoining lentic ("lake-like") environments does not appear to be a limiting factor in the upper Missouri River. Several high plankton producing tributaries had very low flows, and were quite lentic-like. Table 4 gives comparative discharge rates of three South Dakota tributaries (Page 21).

Water works personnel, whose plants utilize the Missouri River as their source of supply, were contacted enroute and without exception their prime concern was the removal of suspended matter causing turbidity. No major taste and odor occurrences resulting from the algae specifically were reported for the Missouri River water. However, the spring run-off produced an odor problem or difficult treatment period common to all water purification plants. The causative agent or agents responsible for the odors during the spring run-off have not been specifically identified. The activity of Actinomycetes has been suggested as a possibility and should bear further and more complete investigation.

Plankton Quantity Expressed as Total Number of Organisms per ml
in the Missouri River and Some of its Tributaries

Missouri River Proper:		Tributary Waters Sampled:	
Fort Peck Reservoir, Montana	160--		
Fort Peck Outlet, Montana	170--		
		--4,560	Milk River, Montana
		--1,420	Wolf Creek, Montana
So. of Wolf Point, Montana	220--		
		--640	Poplar River, Montana
		--4,400	Big Muddy Creek, Montana
Snowden, Montana	440--		
		--480	Yellowstone River, No. Dak.
N. of Yellowstone Mouth	200--		
W. of Williston, No. Dak.	1,200--		
Williston, No. Dakota	640--		
		--320	Little Muddy Creek, No. Dak.
Garrison Dam Site, No. Dak.	560--		
Bismarck, No. Dakota	70--		
		--2,000	Heart River, No. Dakota
		--4,640	Cannonball River, No. Dak.
		--9,040	Grand River, So. Dakota
Mobridge, South Dakota	400--		
Mobridge, South Dakota	360--		
Whitlock, South Dakota	400--		
Pierre, South Dakota	520--		
		--7,800	Bad River, South Dakota
Chamberlain, South Dakota	240--		
Chamberlain, South Dakota	160--		
Ft. Randall, South Dakota	20--		
Yankton, South Dakota	120--		
		--29,160	James River, South Dakota
Vermillion, South Dakota	480--		
		--64,520	Vermillion River, So. Dakota
Vermillion, South Dakota	2,400--		
Elk Point, South Dakota	600--		
		--22,280	Big Sioux, Sioux City, Iowa
Below Big Sioux River	2,320--		
Sioux City, Iowa	300--		
		--2,520	Platte River, Nebraska
Nebraska City, Nebraska	100--		
Rulo, Nebraska	40--		
		--220	Platte River, Missouri
		--170	Kansas River, Kansas
Kansas City, Missouri	60--		
Jefferson City, Missouri	80--		
		--2,940	Moreau River, Missouri
		--140	Osage River, Missouri
		--200	Gasconade River, Missouri
St. Louis, Missouri	160--		
		--140	Mississippi River, Missouri
AVERAGE FOR MISSOURI RIVER	460	7,880	AVERAGE FOR TRIBUTARIES

Organisms per ml

FIGURE 3

PLANKTON POPULATIONS OF THE MISSOURI RIVER VS POPULATIONS OCCURRING IN TRIBUTARIES.

MISSOURI RIVER BASIN PLANKTON* SURVEY

JULY, AUGUST, and SEPTEMBER
1930

*Plankton Organisms expressed as total number per ml.

14-6-

Three South Dakota Tributaries

The Big Sioux, Vermillion, and James Rivers, all of which enter the Missouri, between Yankton, South Dakota, and Sioux City, Iowa, were among the most productive waters encountered in the entire Basin. The proximity of these three tributaries in South Dakota and the diversity of species in the plankton populations made it one of the most interesting areas encountered.

In these three productive tributaries, the general low velocity of flow is conducive to low silt load. Slow currents and quiescence are generally conducive to high plankton production when the waters are rich as they are in the Missouri Basin.

Location of the point of confluence of the Missouri and a tributary river in this area is not always an easy task. It was only with the aid of William Flippin, a local farmer, that the mouth of the Vermillion was located near Burbank, South Dakota. Indefiniteness of tributary mouths in this area is occasioned by shifting of the Missouri River Channel, which may move 5 to 15 miles in a single year and necessitate cutting of new channels by tributaries.

Mr. Flippin directed the writer's attention to an area of land occupied by a portion of the stream bed of the Missouri River and recalled the time when he had farmed in that very region. He had been offered $40,000 for this farm when the river was two miles away. Three years later the river started cutting into his farm at the rate of approximately 50 feet per week. He lost his entire acreage in two years but managed to save the buildings by moving them to a new location.

The James River

The James River originates just below the Devils Lake region in North Dakota and flows south for approximately 400 miles through the cities of Jamestown, North Dakota, and Huron and Mitchell, South Dakota, before entering the Missouri River at a point east of Yankton, South Dakota (Fig. 2).

Eight samples were collected in the stretch south of Jamestown. A rather unique feature of this river was the abundance of filamentous blue-green algae, Aphanizomenon, from Jamestown, North Dakota, all the way to the mouth of the river, a distance of over 250 miles (Table 1). Associated with Aphanizomenon were several genera of diatoms (Cyclotella, Melosira, and Navicula) and a green alga, Actinastrum.

Total plankton populations at seven of the eight points of collection ranged between 20,000 and 29,160 organisms per ml (Table 1). The sample (126) at Huron yielded 12,720 organisms per ml and was the only one to indicate much fluctuation in population densities over 250 miles of the James.

TABLE 1

Plankton Survey of James River Between Jamestown, North Dakota, and Yankton, South Dakota, July, 1950

Sample No.	Point of Collection	Approx. Miles Above Mouth	Total Plankton per ml.	Dominant Organisms
12R	Jamestown, N. Dakota	250	21,360	Aphanizomenon Cyclotella Synedra
12G	Huron, South Dakota Route 14 Bridge	110	12,720	Aphanizomenon Cyclotella
12H	Forestburg Route 37-34 Bridge	88	20,000	Aphanizomenon Cyclotella
12J	Mitchell Route 16 Bridge	66	26,760	Aphanizomenon Cyclotella
12F	Olivet Route 18 Bridge	33	23,840	Aphanizomenon Cyclotella
12E	South of Midway Route 81 Bridge	20	21,200	Aphanizomenon Cyclotella
12D	Yankton Route 50 Bridge	2	25,400	Cyclotella Aphanizomenon Actinastrum
12C	Mouth of James	0	29,160	Cyclotella Aphanizomenon Actinastrum
11B	Missouri Below James River	-20 East	480	Aphanizomenon
13	Missouri Above James River at Yankton Bridge	-5 West	120	No Aphanizomenon Diatoms & Ciliates

Almost 10,000 units or 1,000 millimeters per ml of Aphanizomenon, the dominant organism at all points of collection, were found entering the Missouri at the mouth of the James. Less than 30 millimeters per ml occurred 20 miles downstream and only 15 millimeters could be found at Elk Point, South Dakota, which is 40 miles downstream. It was not found at any greater distance in the Missouri or in any of the samples collected in the Vermillion or Big Sioux Rivers. This evidence would seem to indicate that Aphanizomenon was not multiplying in the Missouri River, and its disappearance undoubtedly resulted from the great dilution brought about by the highly turbid and rapidly flowing waters of the Missouri.

Chemical samples analyzed by the United States Geological Survey revealed the following conditions relative to the presence of primary nutrient materials in the James River at Huron, South Dakota:

Date	Water Temp.	Turb. ppm	Nitrogen(ppm N)			Phosphorus(ppm PO_4)	
			NO_2	NO_3	NH_3	Soluble	Total
10/3/50	47°F	--	0.040	0.15	0.42	0.417	0.677
11/8/50	41°F	3	.001	.08	.20	.457	.766
1/2/51	--	8	.016	.19	.96	1.174	1.373
1/29/51	33°F	10	.001	.20	.08	.613	.996

The Vermillion River

The Vermillion River, a relatively minor tributary (100 miles long) draining a narrow area between the James and Big Sioux River Basins, enters the Missouri near Vermillion, South Dakota, just west of the small town of Burbank (Fig. 2).

Records of a gauging station at Wakonda, South Dakota, for the water year ending September 30, 1949, indicate an average monthly discharge of 126 cfs and a maximum of 2,650 cfs attained March 8. Table 4 shows average monthly discharges of the three South Dakota tributaries.

Seven samples were collected from the Vermillion River between its mouth and a point west of Sioux Falls, South Dakota, during the week of July 8, 1950. Sampling covered a distance of approximately 55 miles north of the Missouri River (Table 2). Dominant organisms were Cyclotella, Nitzschia, and Actinastrum, and not one sample yielded as much as a filament of Aphanizomenon. An increasing trend in plankton densities (Table 2) is suggested in populations found at the points of collection located between the 35-mile station (Sample 11 H) and the mouth (Sample 11 D).

TABLE 2

Plankton Survey of Vermillion River Between Route 16 West of Sioux Falls and Vermillion, South Dakota - July, 8-15, 1950

Sample No.	Point of Collection	Approx. Miles Above River Mouth	Total Plankton per ml.	Dominant Organisms
11K	West of Sioux Falls Route 16 Bridge	55	36,040	Cyclotella Actinastrum Nitzschia
11H	West of Davis Route 18 Bridge	35	18,240	Cyclotella Actinastrum Nitzschia
11G	North of Wakonda Road Route 19 Bridge	22	26,040	Cyclotella Actinastrum Nitzschia
11J	West of Vermillion Route 50 Bridge	4	20,680	Cyclotella Nitzschia
11F	South of Vermillion Morse Bridge	3	21,080	Cyclotella Nitzschia
11E	Opposite Flippin Farm	1	38,360	Cyclotella Nitzschia
11D	River Mouth	-	64,520	Cyclotella Nitzschia
11C	Missouri River Below Mouth	-1/4 East	2,400	Nitzschia Cyclotella Aphanizomenon* Monas
11B	Missouri River Above Mouth	-1/4 West	480	Aphanizomenon

* Aphanizomenon was the dominant organism in the James River and since it was not found in the Vermillion, it seems obvious that it must have been introduced from the James which is twenty miles up the Missouri.

At the station (11 K) 55 miles above the mouth of the Vermillion River, the population of 36,040 plankton organisms per ml does not support a trend of increasing plankton productivity from the headwaters to the mouth of the river. However, it should be noted that this sample (11 K) was collected on the West Fork of the Vermillion at a point where there was little or no perceptible flow. Such a condition might well have resulted in the development of the 36,040 population in a local area and therefore not reflect the true characteristics of a moving stream as was evidenced at other points of collection along the course followed by the Vermillion River (Table 2).

The Big Sioux River

The Big Sioux River forms the boundary between South Dakota and Minnesota for a distance of approximately 80 miles. This river has the largest average monthly rate of flow of the three main tributaries in this area (Table 4).

Seven samples were collected between Sioux Falls and the mouth of the Big Sioux during the week of July 8, 1950 (Table 3) and the same species of Cyclotella and Actinastrum as encountered in the Vermillion River were found almost as commonly. The numerical abundance of another diatom, Stephanodiscus, added a note of variation to this plankton population. A sample (10a(1)) collected four miles above the mouth of the Big Sioux was found to contain 6,250 Stephanodiscus, 6,980 Cyclotella, and 9,600 Actinastrum per ml. Organisms making up the remainder of the 24,460 organisms per ml were Synedra, Navicula, Pediastrum, Scenedesmus, Oocystis, Sphaerocystis, Dictyosphaerium, Hormidium, Coelosphaerium, Microcystis, Trachelomonas, Didinium, and a few undetermined ciliated protozoans. It should be noted that Aphanizomenon, which was so abundant in the James River, was not encountered in the Big Sioux.

The trend of plankton productivity increasing progressively downstream as previously noted in a portion of the Vermillion River was not evident for the Big Sioux River throughout its course. The increasing trend was suggested only by the samples collected between the 80 and 22 mile points of the survey (Table 3). Over the upper 60 miles sampled the populations at four stations were noted to increase from 44,160 to 86,960 organisms per ml. All samples collected between the 22 mile point and the mouth of the Big Sioux River varied between 22,000 and 24,000 organisms per ml. In spite of these rather high population densities only 2,320 organisms per ml could be detected in the Missouri River immediately below the mouth of the Big Sioux River. A sample collected at a point five miles below the mouth yielded only 300 organisms per ml, thus, again showing the great dilution of tributary waters that enter the Missouri River.

TABLE 3

Plankton Survey of Big Sioux River between Sioux Falls, South Dakota and Sioux City, Iowa - July 8-15, 1950

Sample No.	Point of Collection	Approx. Miles Above River Mouth	Total Plankton per ml.	Dominant Organisms
10C (1)	Above Sioux Falls, S.D. Route 16 Bridge	80	44,160	Cyclotella Actinastrum
10C	Below Sioux Falls, S.D. Route 38 - 39 Bridge	77	66,320	Cyclotella Actinastrum
10D	East of Inwood, Iowa Route 18 Bridge	55	71,560	Cyclotella Stephanodiscus Actinastrum
10E	West of Westfield, Ia. Bridge to Route 77	22	86,960	Cyclotella Stephanodiscus Actinastrum
10A (1)	North of Sioux City, Ia. Route 77 Bridge	4	24,460	Cyclotella Stephanodiscus Actinastrum
10B	Opposite Riverside Power Plant-From Boat	3	22,580	Cyclotella Stephanodiscus Actinastrum
10F	Mouth of Big Sioux From Shore	0	22,280	Cyclotella Stephanodiscus Actinastrum
10G	Missouri River Below Mouth of Big Sioux	-1/2 East	2,320	Cyclotella
9	Missouri River South of Sioux City, Ia. (Corps of Engineers) (Material Yards)	-5 East	300	Cyclotella Navicula
10H	Missouri River above Mouth of Big Sioux Elk Point, S.D.	-22 West	600	Monas Aphanizomenon

TABLE 4

Comparative Flow Rates on the South Dakota Tributaries Expressed as Cubic Feet per Second from October 1948 through September 1949

Date	James River	Vermillion River	Big Sioux River
October 1948	43.7	15.2	353
November 1948	62.4	16.5	257
December 1948	47.3	11.1	177
January 1949	48.1	7.1	100
February 1949	31.7	5.5	266
March 1949	1,405.0	811.0	3,856
April 1949	1,529.0	492.0	3,842
May 1949	587.0	78.2	837
June 1949	490.0	34.7	575
July 1949	79.5	14.0	343
August 1949	67.5	16.8	290
September 1949	60.4	14.6	295
Maximum	1,529.0	811.0	3,856
Minimum	31.7	5.5	100
Average	371.0	126.0	933

Variations in the plankton densities that were reported for the James, Vermillion, and Big Sioux Rivers, and the close association of these tributaries marks this area as one deserving of serious consideration for possible year-round study and observation. O. M. Loftus, Chairman of the Zoology Department, University of South Dakota at Vermillion indicated to the writer that graduate students were available who conceivably would be interested in participating in a unified program of study on these rivers over not one but several years. A cooperative study of this nature appears to be a very logical approach to the problem and should bear further investigation.

Lake Mitchell

Lake Mitchell is an impoundment that supplies water to the city of Mitchell, South Dakota (Fig. 2). It has produced serious blue-green algal blooms upon occasions which have caused offensive taste and odors not removable by the local water-purification plant.

On Sunday, July 16, Lake Mitchell was sampled for plankton algae and the same blue-green alga (Aphanizomenon) that occurred in the James River was found to be producing a most prodigious bloom. Just west of the city water intake, colonies of this alga up to two inches long and one-half inch in diameter were noted. Microscopic counts indicated that the water contained better than 8,000 units per ml (8,000,000 per quart). Lake Mitchell drains into the James River and for awhile was believed to be the source of Aphanizomenon in the latter. This idea was quickly discarded when large concentrations of this alga were found farther upstream in the James River (Table 1).

Realizing the potential danger of this population of blue-green algae in the drinking water supply, an attempt was made to contact the water superintendent immediately, but he was out of town for the weekend. With his return to duty, Monday, July 17, complaints on taste and odor in the drinking water, were widespread throughout the city. The cause of the objectionable taste and odor was obvious and not new to the water purification personnel. They immediately applied 2,400 pounds of copper sulfate to the lake using an especially equipped motor boat.

The results of the copper sulfate treatment are expressed in Table 5. Prior to the application of copper sulfate on July 16, light penetration, measured by the Secchi disk was 32 inches. On July 17 at 6:00 P.M. after the copper treatment, light penetration decreased to less than 12 inches. Because there was no appreciable difference in the plankton populations before and immediately after the treatment (Table 5), it was assumed that increased turbidity was due to break up of the

large colonies of Aphanizomenon. On July 18, the plankton population was found to have decreased from over 9,000 to 520 organisms per ml, while the turbidity was again comparable to that of July 16.

The speed with which algal blooms may develop and then in turn be brought under control is illustrated by these data. On July 14, the water plant personnel could see no evidence of an approaching bloom. In less than 48 hours (July 16 - 10:00 A.M.) the writer found the richest growth of Aphanizomenon ever experienced in field collecting. Twenty-four hours after application of copper sulfate Lake Mitchell changed from a pea-soup-like concoction to a clear potable water supply.

Table 5

Plankton Sampling on Lake Mitchell, Mitchell, South Dakota During a Blue-Green Algal Bloom on July 16, 17 and 18, 1950

Organisms Expressed per ml	July 16 10:00 A. M.	July 17* 6:00 P. M.	July 18 11:30 A. M.
Aphanizomenon	8320	9020	320
Anabaena	-	40	40
Cyclotella	40	-	-
Rhodomonas	40	-	-
Stephanodiscus	120	-	40
Schroederia	200	-	-
Trachelomonas	40	120	60
Vorticella	-	-	60
Total	8760	9180	520

* 2,400 lbs. copper sulfate applied during the day, approximating conservatively a dosage of 10 pounds per million gallons (1.2 ppm).

Upper Souris River Area

The Souris River arises in the Province of Saskatchewan, Canada, flows southeast into North Dakota to Velva, then gradually bends around to the northwest and returns to Canada, joining the Assiniboine River in Manitoba.

Lake Darling

An impoundment north of Carpio, North Dakota, on the Souris River, known as Lake Darling, comprises a part of the upper Souris Wildlife Refuge. Plankton populations above and below the dam at Lake Darling (Samples 28A and 28B) were not found to be appreciably different in number of individuals nor in kinds of species. Aphanizomenon was very abundant, comprising 22,700 of a total 24,750 organisms per ml.

Des Lacs Lakes

The Des Lacs Game Refuge is located aproximately 30 miles west of Lake Darling on the Des Lacs River near Kenmare, North Dakota (Fig. 2). A series of cross dikes at the outlets of three natural lakes has formed what are now called the Lower, Middle, and Upper Des Lacs Lakes. This drainage system enters the Souris River near Foxholm, North Dakota.

Six samples were collected over the course of the Des Lacs River from a point above its junction with the Souris River near Foxholm and its headwaters beyond Northgate, Canada (Table 6). A blue-green algal bloom consisting primarily of Aphanizomenon and Microcystis was quite apparent. In fact, the maximum plankton population for the entire survey was found in the water collected from the Des Lacs River near Foxholm, North Dakota (Sample 27). A total of 102,500 organisms per ml was recorded with over 80,000 organisms being Aphanizomenon. Since this alga is a filamentous form, each organism is recorded as a unit of 100 microns of filament. Thus, there would have been the equivalent of over 320 inches of Aphanizomenon in each milliliter of water of this particular sample. Equated in still another form, the Des Lacs River water would have contained more than 27,000 feet or over five miles of Aphanizomenon filaments per quart. It should be noted that the predominant organism in the Middle Des Lacs Lake and at other collection points to the north was Microcystis, with Aphanizomenon making up a small percentage of the total population (Table 6).

Evidence in the way of blue-green drift marks consisting of partially dried Aphanizomenon along the shore line indicated that the bloom still apparent in the Lower Des Lacs Lake had

moved throughout the chain of lakes. At the same time, the predominance of Microcystis in the Upper and Middle Des Lacs with a large population moving into the Lower Des Lacs Lake seems to support the migration of a Microcystis bloom as following closely on the Aphanizomenon bloom (Table 6).

Organisms found in Des Lacs Lakes other than those blue-green genera reported in Table 6 were as follows:

Diatoms	Green Algae		Blue-green Algae
Cyclotella	Actinastrum	Pediastrum	Anabaena
Cymbella	Chlamydomonas	Selanastrum	Coelosphaerium
Navicula	Closterium	Scenedesmus	Gomphosphaeria
Stephanodiscus	Dictyosphaerium	Staurastrum	Merismopedia
Surirella	Gloeoactinium	Spondylosium	
Synedra	Oocystis	Tetraedron	
Flagellates	**Protozoa**	**Rotifers**	**Crustacea**
Euglena	Codonella	Brachionus	Bosmina
Mallomonas	Monas	Keratella	Cyclops
Rhodomonas	Vorticella	Polyarthra	
Trachelomonas		Triarthra	

No attempt was made to determine other than the genus of an organisms at the magnification of 210 X.

If the Souris River Diversion Dam is completed, it is possible that some of the Des Lacs water could be directed into the James River Basin. Recalling that the predominate organism in the James River was Aphanizomenon throughout most of its course, the combination of these two waters would be very likely to result in one of the most serious algal problems in the entire Missouri River Basin. At present, the high plankton productivity in the upper Souris area appears to be favored by the shallow depth of the water and high summer water temperatures that result. The extremely low rates of flow plus the enrichment furnished by the nitrogenous wastes of copious migratory fowl are also major contributing factors.

The Little Missouri River

The Little Missouri River originates in the extreme northeast corner of Wyoming and flows through a small portion of Montana and South Dakota. The main portion of its basin is

TABLE 6

Plankton Survey of the Des Lacs Lakes
on July 24, 1950

Sample No.	Point of Collection	Approx. Miles Above River Mouth	Plankton Organisms per ml			
			Aphanizomenon	Microcystis	Other Forms	Total
29E	Northgate, Saskatchawan - Headwater area	80	160	11,920	5,400	17,480
29D	Upper Des Lacs Lake Rt. 52 Bridge	55	600	18,600	5,840	25,040
29C	Entrance to Middle Des Lacs Lake	45	0	20,880	2,640	23,520
29B	Outlet of Middle Des Lacs Lake	43	40	15,480	5,680	21,200
29A	Outlet of Lower Des Lacs Lake	38	52,000	2,400	7,600	62,000
27	Riveire Des Lacs	10	80,333	4,500	17,667	102,500

in North Dakota where it joins the Missouri River at Elbowoods, a point approximately midway between Williston and Bismarck (Fig. 2).

Only two samples were taken on this tributary. One (No. 32B) near Alazada, Montana, and the other (No. 32) south of Watford City, North Dakota, 50 miles above the mouth. A population of only 540 organisms per ml was found in the headwaters in Montana. At the 50 mile point above the mouth a population of over 24,000 organisms per ml was recorded. The predominating organisms were Cyclotella, Synedra, and Actinastrum.

The same species of Synedra occurred in the headwater sample as was found in highly productive water nearer the mouth. These data suggest that the plankton population increases in the Little Missouri River as it moves down stream.

The Yellowstone River

The Yellowstone River drains southeast Montana and northern Wyoming. Its basin is approximately 400 miles long and 300 miles wide (Fig. 2). The average annual discharge at the mouth of the river, during the ten year period 1931-40, was 6,870,000 acre-feet. The Missouri River above the mouth of the Yellowstone averaged 5,000,000 acre-feet annually during the same period (Ickes, 1944).

Five samples were taken along 150 miles of the Yellowstone (Table 7). The plankton populations were found to be much like Missouri River samples (Fig. 3). In fact, it was soon obvious after leaving the Missouri River that, in reality, the Yellowstone was still characteristically Missouri River water. Above the mouth of the Yellowstone, the name "Big Muddy" no longer characterizes the Missouri but would be more aptly applied to the Yellowstone River.

The diversion of water from the Yellowstone River into gravity flow irrigation ditches at various points along the stream course is common practice. This serves not only to enrich nutrients but to add greatly to turbidity when portions of irrigation water are eventually returned to the Yellowstone.

Plankton populations found in the irrigation ditch (Sample 36A), and in the Yellowstone River channel (Sample 36), were not significantly different (Table 7). Both populations had less than 500 organisms per ml. Such comparatively low productivity apparently results from high turbidity and high current velocity.

TABLE 7

Plankton Survey of the Yellowstone River
from July 31 through August 6, 1950

Sample No.	Point of Collection	Approx. Miles Above River Mouth	Total Plankton per ml	Dominant Organisms
36E	Miles City, Montana	150	1200	Navicula Monas
36D	Fallon, Montana	100	640	Navicula Monas
36C	Glendive, Montana	70	400	Navicula
36A	Fairview, Montana Irrigation Ditch	7	200	Navicula
36	East of Fairview, Montana	7	480	Navicula
35	Missouri River Buford, N.D.	-2 East	200	Navicula

Fort Peck Reservoir

The Fort Peck Dam is located in northeastern Montana, approximately 100 miles west of the North Dakota boundary (Fig. 2). Construction was started in 1933 and storage began in 1937. The four-mile long earth filled dam is the largest structure of its kind in the world. It is 250 feet high with a maximum width of 4,900 feet at the base and 100 feet at the top. A hard surfaced road is maintained across the dam and throughout the area as a tourist route.

The reservoir, when filled to capacity, will cover 245,000 acres, have a shore line of 1,600 miles, a length of 189 miles, a clear width of 16 miles, and a maximum depth of 220 feet.

Widespread sampling by boat in the four-mile area above the dam was completed on August 2, 1950. The water was remarkably clear giving Secchi disk readings of more than three meters (nine feet). In contrast, the disk often disappeared from view at less than one inch depths in the Missouri River below the mouth of the Yellowstone.

All the apparent environmental factors observable in the Fort Peck Reservoir seemed to indicate that conditions were favorable for a rich plankton population, but, productivity was found to be extremely low. A series of samples taken above the dam from the surface to a depth of 90 feet revealed a population of 100 organisms per ml at the surface, 10 organisms at 10 feet, and less than 10 organisms for the remaining depths (Table 8). Immediately above the spillway and below the tunnel outlets, the populations were not appreciably different.

In a dredged area located below the dam, a population of 720 organisms per ml was found. This area is a bay located off the main channel and, is not subjected to turbulence of water passing through tunnels of the power plant. In spite of this apparent environmental advantage, the population was low.

Table 8

Fort Peck Reservoir Plankton Samples
August 2, 1950

Point I (Sample 41B) 1/2 mile East of Water Sports Bay above the Dam.

Depth	Plankton per ml	Water Temp. °F
Surface	100	70°
3M	10	66°
10M	0	64°
20M	0	63°
25M	0	60°
30M	0	57°

Point II (Sample 41) Immediately above Spillway, West Side - 160 per ml

Point III (Sample 41C) Below Tunnel Outlets - - - - - - - - - 170 per ml

Point IV (Sample 41D) South Dredged Area, from Boat - - - - - 720 per ml

The Corps of Engineers at Fort Peck makes periodic field surveys over much of the reservoir area in studying sedimentation rates. It was in their survey conducted from August 10 through August 14, that a series of 25 plankton samples was collected from stations covering a distance of more than 100 miles of the reservoir above the dam. Even with such extensive sampling, no really high plankton productive areas were located. The maximum population (350 organisms per ml) was recorded at Range 1, 18 miles above the dam at a depth of 125 feet (Table 9).

A gradual increase in the average populations, for all depths at any one station, progressively up the reservoir from the dam was noted (Table 9). The maximum population of 290 organisms per ml was found at Range 32, 108 miles above the dam. No record of the population at Range 33, which is 115 miles above the dam, is available as the sample arrived broken. The collector noted the station as the only one in "flowing water" evidently denoting an inflowing current.

TABLE 9

Summary of Plankton Samples Collected by Corps of Engineers
on Fort Peck Reservoir - August 10-14, 1950

Reservoir Miles Above the Dam	Point of Collection	Depth	Temp. °F.	Total Number of Organisms per ml.	Average Number of Organisms at all depths
115	Range 33	Surface	(Sample arrived broken)		
108	Range 32	Surface	73.5	290	290
92	Range 3	Surface	72.5	220	255
	Range 3	40 Ft.	63.0	290	
74	Range 26	Surface	67.5	190	190
	Range 26	50 Ft.	(Sample arrived broken)		
58	Range 23	Surface	66.0	220	155
	Range 23	80 Ft.	54.0	90	
37	Range 2	Surface	64.5	310	245
	Range 2	80 Ft.	52.5	180	
18 (West)	Range 1	Surface	67.0	40	
	Range 1	75 Ft.	59.0	120	170
	Range 1	125 Ft.	50.5	350	
15 (So. Fork)	Range 6	Surface	68.0	10	
	Range 6	50 Ft.	63.0	10	43
	Range 6	108 Ft.	52.0	110	
5	Five Mile Point	Surface	(Sample arrived broken)		
	Five Mile Point	80 Ft.	53.0	0	25
	Five Mile Point	178 Ft.	49.5	50	
1	Dam Face	Surface	68.5	10	
	Dam Face	80 Ft.	(Sample arrived broken)		35
	Dam Face	172 Ft.	50.0	60	
Above Spillway	Range 8	Surface	67.5	20	
	Range 8	50 Ft.	64.0	80	40
	Range 8	82 Ft.	53.0	20	

Reasons for the apparent increase in productivity up the reservoir are not evident. A summary of chemical analyses completed during October 1948, (Appendix C) allows for speculation. The average nitrate nitrogen (in ppm N) was found to vary progressively from .27 ppm at the one-mile point to .74 ppm at the 92 mile point (Table 10). However, careful study of both the biological and chemical relationships throughout an annual cycle are necessary before attempting any such correlation as suggested by these data.

Fort Peck Reservoir appears to have some characteristics that are similar to those of the Great Lakes. In size and depth, Fort Peck might be considered a miniature Lake Michigan. Organisms encountered in the plankton tow net collections were essentially similar to those reported in Lake Michigan (Damann, 1945). The genera noted in Fort Peck Reservoir are listed below.

If this comparison could be extended to cover regular observations over an entire annual cycle, it is believed that Fort Peck Reservoir would not be considered low in productivity. The annual plankton population cycle would be represented by a bimodal curve with a spring pulse occurring in April, May or June and a fall pulse in September, October or possibly November. Separating the two periods of high productivity would be an interval of extremely low productivity which would usually occur in August. This curve has been repeated in Lake Michigan with very little variation for the past twenty-five years (Fig. 4). It is believed that the August sampling on Fort Peck was done during the summer low in productivity. Annual studies in the area offer the only means to confirm or deny such a possibility.

Plankton Organisms Encountered in a Tow Net Collection
Above the Fort Peck Dam on August 2, 1950

Diatoms		Green Algae	Blue-green Algae
Achnanthes	Melosira	Chlamydomonas	Aphanizomenon
Amphiprora	Navicula	Coelastrum	Chroococcus
Asterionella	Stephanodiscus	Dictyosphaerium	Microcystis
Cyclotella	Synedra	Oocystis	
Cymbella	Tabellaria	Pediastrum	
Fragilaria	Nitzschia	Scenedesmus	

Flagellates	Protozoa	Rotifers	Crustacea
Ceratium	Codonella	Brachionus	Bosmina
Dinobryon	Monas	Keratella	Canthocamptus
Euglena		Polyarthra	Cyclops
Phacus			Daphnia
Peridinium			
Rhodomonas			

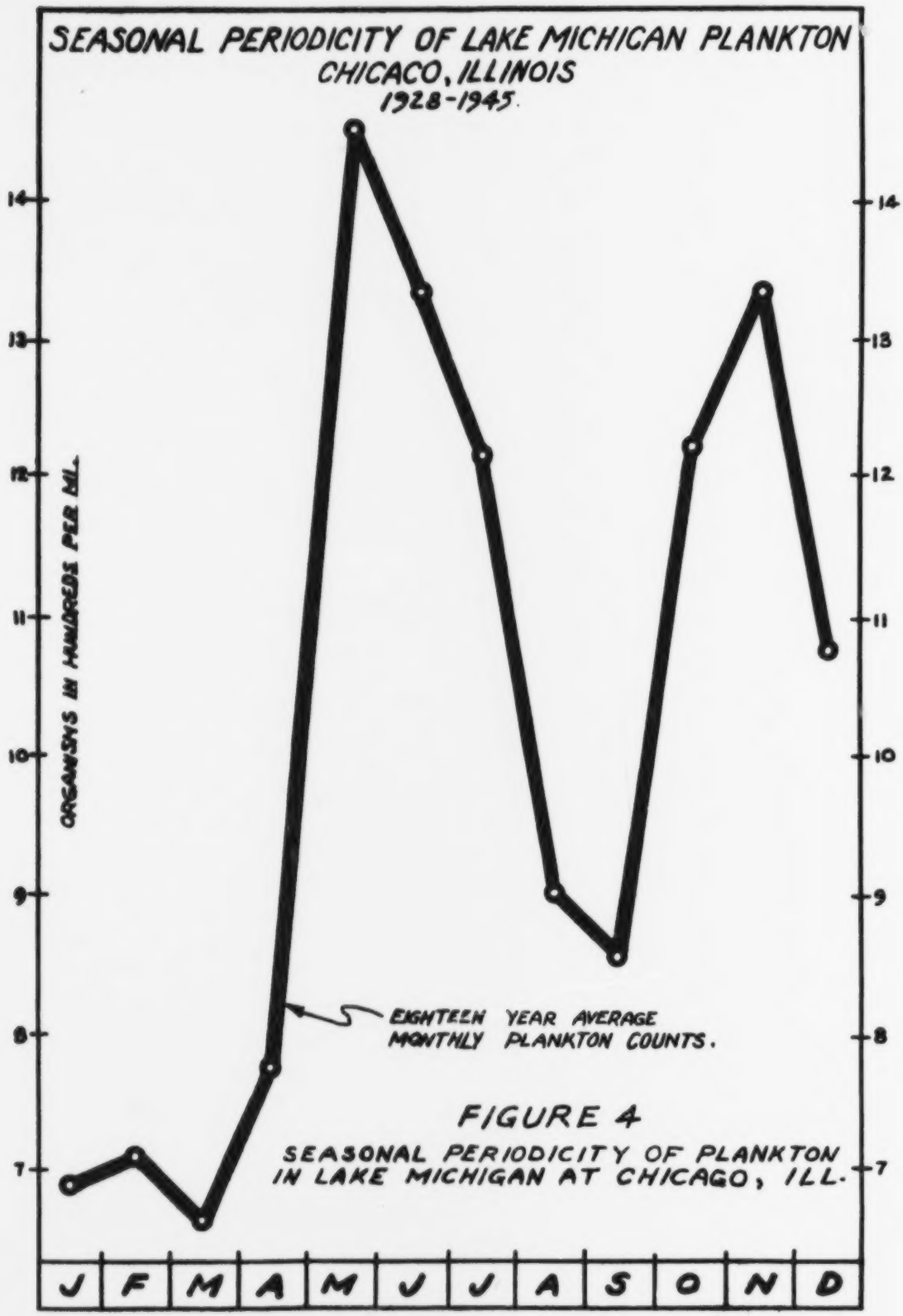

FIGURE 4

SEASONAL PERIODICITY OF PLANKTON IN LAKE MICHIGAN AT CHICAGO, ILL.

TABLE 10

Summary of Nitrate Nitrogen in PPM Found Occurring
in Fort Peck Reservoir During August 1948

Mile Point Above Dam	Location	Depth	Nitrate Nitrogen ppm*	Average Nitrate Nitrogen* per Station
92	Range 3	Surface	1.17	0.74
	Range 3	45 Ft.	0.29	
74	Range 26	Surface	0.18	0.38
	Range 26	70 Ft.	0.56	
37	Range 2	Surface	0.22	0.36
	Range 2	90 Ft.	0.50	
18	Range 1	Surface	0.16	0.29
	Range 1	90 Ft.	0.43	
1	One-mile	Surface	0.27	0.27
	One-mile	190 Ft.	0.27	

* The table in Appendix C expresses these results in Nitrate (NO_3). Nitrate (NO_3) ÷ 4.43 = Nitrate nitrogen.

The Platte River Basin

The main Platte River is formed by the junction of the North and South Platte Rivers near the city of North Platte, Nebraska. It flows eastward across the state of Nebraska and enters the Missouri River south of Omaha at Plattsmouth, Nebraska (Fig. 2).

The South Platte River and its principal tributaries originate in northeastern Colorado and in the extreme southeastern corner of Wyoming. The Antero Reservoir of the Denver Board of Water Commissioners receives water from the South Platte headwater streams as they flow into the high flat valley known as South Park (Ickes, 1944).

The North Platte River rises from several tributary mountain streams in North Park, Colorado, and then flows north into Wyoming. In so doing it makes a broad loop into central Wyoming before turning southeast to follow a diagonal southeasterly line between Guernsey, Wyoming, and North Platte, Nebraska. Seminoe, Pathfinder, Alcova, and Guernsey Reservoirs are all operating on the North Platte in Wyoming.

A series of 22 samples was collected over approximately 700 miles of the Platte River course in Nebraska and Wyoming. In Table 11, it should be noted that the sampling was completed during July, August, and September and is, thus, too great an interval of time to allow for a complete sequence comparison over the entire collecting area. In spite of this time interval, there seems to exist a rather pronounced tendency suggesting increased productivity from the headwaters to the mouth of the Platte River. More extensive sampling on the North Platte River during July, August, October, and November, 1950, by Neel (1951) has indicated that the plankton exhibits a downstream density pattern that responds to the effect of local conditions (domestic sewage, industrial wastes, irrigation drainage, etc.) more than developing a continuous and gradual increase with distance downstream. The data in Table 11 would seem to support such a contention for the North Platte and at least a portion of the Platte River.

The North Platte River

Pathfinder, Alcova, and Guernsey Reservoirs, all located in the first 100 miles of the North Platte River basin, failed to yield plankton populations of any abundance during July and August 1950. This low productivity probably results from the fact that the headwaters of the North Platte are primarily derived from melting snows in the Colorado and Wyoming mountain ranges, and are, therefore, low temperature waters not enriched chemically with tributaries coming from basically agricultural or plowed land.

Below Guernsey Reservoir, the North Platte basin widens into a broad plain which extends to and beyond the junction with the South Platte River. Plankton populations appeared to increase in this area for approximately the next 150 miles of the river from 980 organisms per ml at Guernsey, Wyoming, to 8,640 organisms per ml at a point where the Platte River is considered to be entering Lake McConaughy at Lewellen, Nebraska (Table 11).

It should be noted that the dominant organisms in this stretch of the North Platte were more typically periphyton species than plankton species. Neel has noted (1951) a decidedly local area increase in density of plankton in the first 20 miles below the Guernsey Reservoir. He suggested that it might have resulted from enrichment of water caused by oxidation of decomposition materials present in bottom water flowing from the reservoir.

Lake McConaughy vs. Guernsey Reservoir

Lake McConaughy is probably the largest single body of water in Nebraska. It resulted from construction of Kingsley Dam on the North Platte River north of Ogalalla, Nebraska (Fig. 2). As a result, water is backed up to Lewellen, Nebraska, a distance of approximately 25 miles. Due to lack of time, sampling was restricted to the area immediately above and below the dam.

Vertical sampling from the surface to a depth of 26 meters revealed a maximum population of 5,170 plankton organisms per ml at the 5 meter depth, followed by 3,460 at 10 meters. The surface sample yielded only 550 organisms while a population of 350 was found at 26 meters (Table 12). The same kind of sampling in Guernsey Reservoir (Table 12) showed a maximum population of 1,080 organisms at the surface with essentially uniform counts to a depth of 15 meters.

The rather low population of 550 organisms per ml at the surface of Lake McConaughy as compared to 5,170 organisms at five meters can be explained in part by the complete absence of Asterionella in the surface sample. Why Asterionella did not occur at the surface when it was found in abundance at all other depths is not evident. The temperature data (Table 12) reveal very little variation to a depth of 10 meters. The difference of 12° F. (6.7° C.) noted between 10 and 26 meters would suggest the presence of a thermocline and the lowest population of 320 organisms per ml would be expected at that depth.

The maximum Secchi disk readings for the entire Missouri River Basin were found in Lake McConaughy. Readings up to approximately 12 feet (3-1/2 meters) correlated well with the location of maximum plankton populations.

The dominant genera in both Guernsey Reservoir and Lake McConaughy were diatoms (Asterionella, Fragilaria, Tabellaria, and Melosira). Yet, the Platte River water entering Lake

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TABLE 11

Plankton Survey of the North Platte and Platte Rivers
Between Pathfinder Reservoir, Wyoming and the Missouri River

Sample No.	Point of Collection	Date	Approximate Miles Above River Mouth	Plankton Results	
				Total No. Per ml.	Predominant Organisms
84	Pathfinder Reservoir	7-8-50	737	418	Asterionella, Fragilaria Melosira
86	Alcova Reservoir	7-9-50	727	14	Asterionella, Fragilaria
56	Douglas, Wyoming	8-13-50	610	600	Asterionella, Navicula Fragilaria
55 A,B,C,D,E	Guernsey Reservoir	8-12-50	536	672	Asterionella, Navicula Fragilaria
54	Guernsey, Wyoming	8-12-50	535	980	Asterionella, Navicula Fragilaria
56 A	Scottsbluff, Nebraska	8-14-50	459	2,860	Navicula, Synedra
56 B	Bridgeport, Nebraska	8-14-50	427	3,820	Navicula, Synedra
56 C	Lewellen, Nebraska	8-14-50	369	8,640	Navicula, Synedra
60 A,B,C	Lake McConaughy Res.	8-15-50	344	2,375	Asterionella, Fragilaria
60 D	Lake McConaughy, below dam	8-15-50	343	690	Asterionella, Fragilaria
87	Keystone, Nebraska	9-15-50	337	1,860	Navicula, Synedra
89	Sutherland, Nebraska	9-15-50	310	6,120	Fragilaria, Navicula
91	Maxwell, Nebraska	9-15-50	275	5,040	Navicula, Synedra
92	Gothenburg, Nebraska	9-15-50	255	2,060	Navicula, Cyclotella
93	Lexington, Nebraska	9-15-50	230	3,080	Navicula, Cyclotella
94	Kearney, Nebraska	9-15-50	195	3,040	Navicula, Cyclotella
95	Wood River, Nebraska	9-15-50	170	4,920	Navicula, Cyclotella,
96	Columbus, Nebraska	9-15-50	100	7,880	Navicula, Cyclotella, Scenedesmus
97	North Bend, Nebraska	9-15-50	70	17,820	Synedra, Navicula, Scenedesmus
98	Leahard, Nebraska	9-15-50	50	20,760	Synedra, Navicula, Scenedesmus
99	Ashland, Nebraska	9-15-50	30	30,080	Synedra, Navicula, Scenedesmus
100	Creapolis, Nebraska	9-15-50	3	31,320	Synedra, Navicula, Cyclotella Scenedesmus
7	Missouri River Nebraska City, Neb.	7-6-50	-25	100	Navicula

TABLE 12

Plankton Survey of the Guernsey Reservoir and Lake McConaughy on the North Platte River in Wyoming and Nebraska

Sample No.	Point of Collection	Temp. °F.	Number of Organisms per ml.	Dominant Organisms
Guernsey Reservoir, August 12, 1950				
55 A	Surface, above dam	68°	1080	Cyclotella Rhodomonas
55 B	2-1/2 meters	67°	680	Rhodomonas
55 C	5 meters	68°	520	Rhodomonas
55 D	10 meters	67°	400	Fragilaria
55 E	15 meters (bottom sample)	67°	680*	Diatoms
54	North Platte River Guernsey, Wyoming	64°	980	Asterionella Fragilaria
Lake McConaughy, August 15, 1950				
60	Surface, above dam	72°	550	Fragilaria
60 A	5 meters	71°	5170	Asterionella Fragilaria
60 B	10 meters	70°	3460	Asterionella Fragilaria
60 C	26 meters	58°	320	Asterionella Fragilaria
60 D	Below spillway	58°	690	Asterionella Fragilaria

* 340 dead diatom shells included.

McConaughy at Lewellen, Nebraska, had a plankton population of 8,640 organisms comprised mainly of two different genera of diatoms (Navicula and Synedra). Such results would seem to indicate that the latter two genera of diatoms mentioned were more typical of the periphyton species described by Neel (1951) and, thus, had their origin somewhere along the river course rather than in Guernsey Reservoir.

The Platte River

Sampling on the Platte River below Lake McConaughy was done by Allan Johnson of the Nebraska State Health Department on September 15 and 16 (Samples 87-100, Appendix A). No attempt should be made to correlate these September populations directly with those recorded in July and August for the reservoirs on the North Platte River and Lake McConaughy in Table 11.

The 12 samples collected over 320 miles of the Platte River between Keystone and Oreapolis, Nebraska, revealed a very definite trend toward increased plankton productivity downstream (Table 11). The minimum population of 1,860 organisms per ml was found at Keystone, the 320 mile point, and the maximum population of 31,320 organisms per ml occurred at Oreapolis, the three-mile point. With the exception of the samples collected at Sutherland and Maxwell, Nebraska, the population increase was found to be gradual and continuous across the state to the Missouri River.

The South Platte River

Effects of the South Platte River upon the plankton populations of the Platte River are not definitely known. A sample (No. 61) collected south of Ogallala, Nebraska, by the writer, on August 16, yielded a plankton population of 3,860 organisms per ml, mainly diatoms (Navicula and Synedra). On September 15, the same station was sampled again (No. 88) by the Nebraska State Health Department, and a population of 3,600 organisms was found. The same species of diatoms reported in August still predominated.

At Hershey, Nebraska, a point approximately 15 miles above the confluence of the North and South Platte Rivers, a population of 3,240 organisms per ml was recorded on September 15. The same diatoms (Navicula and Synedra) were dominant. In fact, these same genera persisted and increased in numbers in the Platte River. The Asterionella, Fragilaria, and Tabellaria complex of diatoms found in the reservoirs of the North Platte Riverwas absent in the main Platte River.

The Kansas River Basin

The Kansas River Basin has an area of approximately 60,000 square miles with roughly 16 per cent in Colorado, 28 per cent in Nebraska, and 56 per cent in Kansas. Principal rivers in the basin are the Kansas, Big Blue, Republican, Smoky Hill, Solomon, and Saline (Fig. 2). The Kansas River is formed by the union of the Smoky Hill and Republican Rivers at Junction City, Kansas, and flows in an easterly direction less than 150 miles to its confluence with the Missouri River at Kansas City, Kansas.[1]

The plankton populations encountered in the Kansas River Basin during August 16 through 21 would seem to indicate a trouble-free water as far as plankton organisms were concerned (Fig. 2). Unfortunately, most of the rivers in the basin were at flood stage due to the heavy rains and thus not characteristic nor comparable to the sampling completed on the other major tributaries of the Missouri River.

Taste and odor problems are not new in the Kansas River System. Reference has been made to water treatment problems due to algae in the Kansas River Basin Water Pollution investigation (1949). In fact, it was troublesome experiences with these algae in Kansas that occasioned this study of the entire Missouri River Basin. Thus, it is rather ironical that the Kansas River Basin should be found trouble free. Such results serve to amplify the need for studies covering a complete annual cycle in an area rather than merely spot sampling.

Enders Reservoir

Enders Reservoir, located on Frenchman Creek south of Imperial, Nebraska, was sampled on August 16, 1950. For all practical purposes, construction of the dam was complete but no attempt had been made to start filling the reservoir. A plankton population of 1,160 organisms per ml was found to be comprised primarily of the diatoms, Navicula and Synedra. These, incidentally, were the same genera that dominated the South Platte River sample collected on the same date near Ogallala, Nebraska.

Kanapolis Reservoir

The Kanapolis Dam is located on the Smoky Hill River, 25 miles southwest of Salina, Kansas. Since its completion in 1948, it has formed a reservoir over 12 miles long with an average depth of about 15 feet.

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[1] Kansas River Basin Water Pollution Investigation. Federal Security Agency, Public Health Service Report. June 1949.

Ten samples were collected by boat over the area five miles above the dam on August 20, 1950. A maximum population of 1,570 organisms per ml comprised principally of Aphanizomenor. and Microcystis was found occurring off Langley Point, one half mile above the dam. At the control tower adjacent to the dam the same species were dominant in a population of 1,155 organisms per ml. Progressing away from the face of the dam the populations were all less than 500 organisms per ml, yet dominated by the same blue-green algae (Table 13).

While none of these plankton populations would be considered at nuisance stage, all indications pointed to the possibility that two blue-green algae (Aphanizomenon and Microcystis) could and probably would develop rich populations. The high winds and violent wave action which had accompanied a rather extensive sequence of local thundershowers appeared to be factors not favoring the immediate or local development of an algal bloom. The wind was continuous from the northwest and appeared to be accumulating blue-green algae in coves along the south shore (Samples 66A and 66F of Table 13).

Water temperatures as high as 78° F. found in the cove areas of the reservoir were factors in favor of the growth and development of blue-green algae. Vertical measurements (Table 13) indicate a rather uniform temperature from surface to bottom (76° to 74° F.).

Data collected by Tiemeier (1951) during July and August, 1950, show that the phytoplankton increased from 23 to over 200 organisms per ml when the reservoir water level raised 22 feet from 1,461 to 1,483 feet mean sea level. The maximum individual sample reported had over 9,000 organisms per ml. Had the water level remained relatively constant, it would seem reasonable to assume that a greater increase in water temperature might have resulted. Without the dilution effect of the high water a prodigious bloom of blue-green algae might have developed over the entire reservoir.

The most common blue-green algae reported by Tiemeier were Aphanizomenon, Spirulina, Anabaena, and Phormidium. The most prevalent green algae were Microspora, Spirogyra, and Ophiocytium while diatoms and desmids were reported too few to count. The average plankton population found by the writer on August 20, 1950, for seven stations on Kanapolis Reservoir was approximately 570 organisms per ml. When one considers the fact that Tiemeier reported a population of 2,714 organisms per ml on August 11, and 284 organisms per ml on August 28, the postulated population from the Tiemeier phytoplankton curve for August 20 would be somewhere between 400 and 1,000 organisms per ml. The recorded value of 570 organisms per ml by the direct count method would seem to support the authenticity of the simplified method used by the writer in this survey.

TABLE 13

Plankton Survey of the Kanapolis Reservoir
on the Smoky Hill River, in Kansas - August 20, 1950

Sample No.	Miles Above Dam	Point of Collection	Secchi Disk	Temp. °F.	Number of Organisms per ml.	Dominant Organisms
66 C	5	Horsethief Cove	15"	72°	350	Aphanizomenon
66 D	3	Yankee Cove	24"	75°	230	Aphanizomenon
66 E	2	Lapham Point	25"	73°	150	Aphanizomenon
66 G*	1	Surface	53"	76°	430	Mycrocystis
66 H*	1	5 meters	-	75°	110	Monas
66 I*	1	10 meters	-	74°	50	Monas
66 B	1/2	North end of dam	54"	71°	150	Aphanizomenon Microcystis
66 F	1/2	Langley Point	41"	74°	1570	Aphanizomenon Microcystis
66 A	0	Control Tower	54"	71°	1155	Aphanizomenon
66	-1/2	Below Spillway	-	72°	80	Monas

* Vertical series of samples, one mile off the center of the dam.

Holton Reservoir

Holton, Kansas, completed a small impoundment on Straight Creek during 1947 to insure the city a constant water supply. The first water went over the spillway in September of 1949. However, the lake water was not put through the filtration plant until March 15, 1950.

The drainage area of the reservoir was estimated at 900 acres of which 60 per cent was in grassland. Several erosion control dams were placed in the ravines entering the reservoir, thus preventing much of the turbidity that ordinarily develops from run-off waters. Secchi disk readings up to two meters were common over most of the reservoir indicating the effectiveness of the control measures. However, beginning in April, 200 pounds of copper sulfate were routinely applied to the reservoir by boat each Saturday. On July 3, plankton populations of 420 organisms per ml at the surface and 700 per ml at a depth of three meters occurred. A second sample on August 21, yielded 1,240 organisms per ml. Local authorities reported the reservoir free of algae in nuisance quantities since the beginning of operations and attribute such results to the periodic use of copper sulfate.

Horton Reservoir

An impoundment on Mission Creek was completed by the City of Horton, Kansas, in 1923. The 200 acre lake that resulted is known as Mission Lake. Although this reservoir is located in the same immediate area as the Holton Reservoir, there had been no use of copper sulfate for algal control. Plankton populations in that part of the lake near the water intake on July 4, 1950, were all less than 200 organisms per ml.

The problem of greatest concern in Mission Lake was the ever present turbidity. It was reported that in its 27 years of existence the reservoir had never really cleared up. Lack of control over farming practices in the drainage area, feeding habits of the large carp populations, and unlimited use of speed boats were all advanced as contributing causes of the turbidity. The Secchi disk was noted to disappear in less than 8 inches (20 cm) in Mission Lake whereas in the one year old Holton Reservoir the Secchi disk could be seen at a depth of over six feet (2 meters).

Reservoir Plankton vs. Stream Plankton

It was rather generally noted in the survey that the artificial lakes or reservoirs created by dams in the Missouri River Basin were not highly productive. Six such reservoirs located in Montana, South Dakota, and Wyoming yielded an average plankton population of only 374 organisms per ml. Sampling points below each of these reservoirs, in the rivers fed by overflow or bottom

release waters from the dams, were without exception more productive. They were found to contain an average population of 2,198 organisms per ml (Table 14). Such results are contrary to what we know of the action of plankton in streams below natural lakes in Michigan (Chandler, 1937).

Data collected by Neel (1951) over more than 300 miles of the North Platte River indicate that the plankton show response to local conditions with densities increasing and decreasing rather irregularly. Below Alcova Reservoir, where surface water only was released, the lake plankters decreased. However, below Guernsey and Kingsley Reservoirs, when water from the hypolimnion was discharged, the lake plankton increased. Oxidation of anaerobic compounds with the production of nitrates and phosphates from hypolimnion water was advanced as possible cause for the increased productivity.

Seven other reservoir lakes in Wyoming, Nebraska, and Kansas were sampled and in each instance no sample was obtained below the lake for comparative purposes. Lack of such a sample resulted either because there was little or no representative flow from the reservoir or a sampling point was not accessible. The fact that the average count for these reservoirs was 1,010 organisms per ml may or may not be related to the effect of low flow from the impoundment (Table 15).

PRESENTATION OF CHEMICAL DATA

Chemical sampling in portions of the Missouri River Basin during 1950-1951 was carried on through the cooperation of three different laboratories and was completely independent of plankton sampling. These laboratories were the Nebraska State Department of Health, Lincoln, Nebraska; the State Hygienic Laboratory, Iowa City, Iowa; and the Geological Survey of the United States, Department of the Interior. Since neither points of collection nor the sampling times necessarily coincided with the plankton sampling, there is little justification in most instances for making direct correlations with biological productivity. Permanent collecting stations were established and sampled at regular intervals over a period as long as a year. Data covering such an interval of time reveal in part the relationships of seasonal changes to chemical changes of the environment and, therefore, deserve consideration. The results are discussed independently for each laboratory participating in the study. Only a portion of the results of these studies are included in the report, the last samples reported upon being those taken in January 1951.

A report on the chemical analyses of the water in Fort Peck Reservoir was furnished by the Corps of Engineers, Fort Peck, Montana. These analyses were made in August 1948. They are summarized in Appendix C.

TABLE 14

Plankton Abundance in and below the Reservoir Lakes in the Missouri River Basin during August, 1950

No.	Reservoir	Location	Source	Plankton per ml		Date of Completion
				In Res.	Below	
1.	Ft. Peck	Montana	Missouri R.	160	220	1937
2.	Belle Fourche	So. Dakota	Belle Fourche R.	30	7880	1911
3.	Deerfield	So. Dakota	Castle Creek	820	1020	1945
4.	Angostura	So. Dakota	Cheyenne R.	140	610	1949
5.	Alcova	Wyoming	North Platte R.	14	600	1938
6.	Guernsey	Wyoming	North Platte R.	1080	2860	1927
			Average	374	2198	

TABLE 15

Plankton Abundance in Reservoirs where Samples were not Available below the Impoundment for Comparative Purposes as in Table 14.

No.	Reservoir	Location	Source	Plankton per ml. In Res.	Date of Completion
7.	La Prele	Wyoming	La Prele Creek	780	1910
8.	Pathfinder	Wyoming	No. Platte R.	409	1909
9.	Lake McConaughy	Nebraska	No. Platte R.	2375	1938
10.	Enders Res.	Nebraska	Frenchman Creek	1160	1950
11.	Kanapolis Res.	Kansas	Smoky Hill R.	517	1948
12.	Holton Lake	Kansas	Straight Creek	1240	1947
13.	Mission Lake	Kansas	Mission Creek	592	1924
			Average	1010	

State Hygienic Laboratory, Iowa City, Iowa

The State Hygienic Laboratory of Iowa analyzed a total of 49 samples from the Missouri River between July 19, 1950, and January 4, 1951. These samples were collected at approximately two week intervals from four locations on the Missouri River. The points of collection were as follows:

760 mile point	Sioux City, Iowa
732 " "	Whiting, Iowa
635 " "	Council Bluffs, Iowa
579 " "	Nebraska City, Nebraska

A summary of all the chemical samples analyzed for each station comprises Appendix D.

Missouri River
July 1950--January 1951

The Missouri River water temperature varied from 32° F (0° C) to 79° F (26° C) between July 1950 and January 1951. The maximum at each of the four stations was recorded in mid-August after which the decline in temperature was gradual into the first week of December when the minimum of 32° F (0° C) was reached. During this same period, the pH values were found to vary from 7.8 to 8.6.

Turbidity

The maximum turbidity of 1,900 ppm was recorded at Nebraska City, Nebraska, on August 2. The minimum of 25 ppm occurred at the same station on December 20. This value is far below the 20,000 to 100,000 ppm maxima reported by several water plants using Missouri River water. It is obvious that such extremely high turbidities are characteristic only during the spring season.

Nitrogen and Phosphorus

The nitrogen and phosphorus analyses for Missouri River water varied as follows:

	Minimum		Maximum
Ammonia nitrogen	0.001	to	0.23 ppm
Nitrite nitrogen	0.0008	to	0.04 ppm
Nitrate nitrogen	0.19	to	0.9 ppm
Soluble phosphorus (PO_4)	0.075	to	1.0 ppm
Total phosphorus (PO_4)	1.25	to	16.6 ppm

The maximum total phosphorus concentrations (expressed as PO_4) at each station occurred in late September and early October, varying at the four collecting stations as follows:

Sioux City, Iowa	760 mile point	9.8 ppm	Oct. 4
Whiting, Iowa	732 " "	9.4 ppm	" "
Council Bluffs, Iowa	635 " "	16.6 ppm	" "
Nebraska City, Neb.	579 " "	12.6 ppm	Sept. 27

The results for alkalinity, calcium, magnesium, chlorides, sulfates, silicates, sodium, and potassium did not appear unique in respect to quantity. These data are available as Appendix D.

The United States Geological Survey

The United States Geological Survey analyzed 58 samples during October, November, December 1950, and January 1951. Twenty-five samples were collected from the Missouri River, 21 from the James, North Platte, South Platte, and Bighorn Rivers; and, 12 from Alcova, Guernsey and Angostura Reservoirs. Individual analyses are included as Appendix E.

Missouri River
October 1950--January 1951

All of the U. S. Geological Survey samples from the Missouri River were collected at Pierre and Yankton, South Dakota, except two. They were collected at Toston, Montana, which is approximately 20 miles above Three Forks, Montana, the point where the Madison, Jefferson, and Gallatin Rivers join to form the Missouri River (Fig. 2).

Water temperatures had already passed the summer maximum before this series of sampling was started. An October maximum of 53° F (11.7° C) was noted to decrease gradually to 32° F (0° C) in January. A minor variation of only 7.8 to 8.0 was recorded for pH.

Turbidity

Turbidity varied from 70 to 600 ppm at Yankton and Pierre, South Dakota; and only 3 to 30 ppm at Toston, Montana. During November 1950, turbidity was found to increase approximately 100 ppm (400 to 500 ppm) between Pierre and Yankton, South Dakota. In January 1951 an increase from 3 ppm at Toston, Montana, to 190 ppm at Sioux City, Iowa, was evident. Between Sioux City, Iowa, and Nebraska City, Nebraska, turbidity remained relatively constant (Table 16).

Nitrogen and Phosphorus

At Yankton and Pierre, South Dakota, the 850 and 1100 mile points, respectively, on the Missouri River, the concentrations of nitrogen and phosphorus were found to vary as follows:

	Minimum		Maximum
Total Nitrogen	0.27	to	1.2 ppm
Ammonia Nitrogen	0.0	to	0.42 ppm
Nitrite Nitrogen	0.0	to	0.005 ppm
Nitrate Nitrogen	0.15	to	0.66 ppm
Soluble phosphorus (as PO_4)	0.018	to	0.417 ppm
Total phosphorus (as PO_4)	0.040	to	5.76 ppm

The maximum of 5.76 ppm for total phosphorus (expressed as PO_4) was found at Yankton, South Dakota, on November 9, 1950. Samples collected at other points on the Missouri River during the first week in November by the Iowa Laboratory* were found to vary with respect to total phosphorus.

		Total Phosphorus (PO_4)	
Pierre, South Dakota	1100 mile point	0.558 ppm	Nov. 9
Yankton, South Dakota	850 " "	5.76 ppm	Nov. 9
Sioux City, Iowa*	760 " "	1.25 ppm	Nov. 1
Whiting, Iowa*	732 " "	1.90 ppm	Nov. 1
Council Bluffs, Iowa*	635 " "	2.50 ppm	Nov. 1
Nebraska City, Nebraska*	579 " "	3.12 ppm	Nov. 8

During January 1951, seven chemical samples were collected on the Missouri River between Nebraska City, Nebraska,* and Toston, Montana. An increase in mineral constituents of the water occurred with increasing distance from the headwaters (Table 16). Some of the changes apparent between Toston, Montana, and Nebraska City, Nebraska, were as follows:

	Toston, Montana	Nebraska City Nebraska*	Maximum & Location
Turbidity, ppm	3	170	190.00 Sioux City, Ia.*
Ammonia Nitrogen, ppm	0.03	0.08	0.09 Pierre, S.D.
Nitrite Nitrogen, ppm	0.0	0.013	0.022 Sioux City, Ia.*
Nitrate Nitrogen, ppm	0.15	0.54	0.66 Yankton, S.D.
Total Nitrogen, ppm	0.37	2.04	2.04 Whiting, Ia.*
Soluble Phosphorus (as PO_4) ppm	0.037	0.125	1.00 Council Bluffs, Iowa*
Total Phosphorus (as PO_4) ppm	0.254	1.30	3.40 Council Bluffs, Iowa*

* Analyses by State Hygienic Laboratory, Iowa City, Iowa.

Table 16

Chemical Analyses of the Missouri River and Two Tributaries
Between Nebraska City, Nebraska, and Toston, Montana, during January 1951

Point of Collection	Miles Above Mouth	Turbidity (ppm)	Nitrogen Content (ppm)				Phosphorus (ppm PO_4)	
			NH_3	NO_2	NO_3	Total	Soluble	Total
Toston, Mont. (B-43)	2000	3	.03	0	.15	.37	.037	.254
Bighorn River (B-57)		(15)	(.03)	(.003)	(.59)	(.87)	(.043)	(.285)
Pierre, S. D. (B-49)	1100	70	.09	.003	.38	.87	.150	.227
Yankton, S. D. (B-53)	850	95	.06	.005	.66	.85	.034	.288
James River (B-42)		(8)	(.96)	(.016)	(.19)	(1.76)	(1.17)	(1.37)
Sioux City, Iowa*	760	190	.001	.022	0.51	1.54	0.94	1.80
Whiting, Iowa*	732	170	.08	.013	0.54	2.04	0.125	1.30
Council Bluffs, Iowa*	635	160	.06	.011	0.56	1.62	1.00	3.40
Nebraska City, Neb.*	579	170	.08	.013	0.54	2.04	0.125	1.30

* State Hygienic Laboratory, Iowa City, Iowa, results.

As shown in Table 16, the greatest nutrient enrichment seems to occur below Yankton, South Dakota. The James, Vermillion, and Big Sioux Rivers located between Yankton, South Dakota, and Sioux City, Iowa, previously have been shown to contribute high plankton populations to the Missouri River. It is not unreasonable to suspect these sources as being partly responsible for this nutrient enrichment. A chemical sample analyzed from the James River at Huron, South Dakota, which is 110 miles above the mouth of the river, has been included in Table 16 for comparative purposes. In each instance, except turbidity and nitrate nitrogen, the concentrations of other forms of nitrogen and soluble and total phosphorus expressed as PO_4 are significantly higher in the James River than in the Missouri River at or above Yankton, South Dakota (Table 16).

An individual sample from the Bighorn River (Table 16), tributary to the Yellowstone, would seem to indicate that there is little nutrient enrichment contributed in this area. Between Miles City and Fairview, Montana, where the Yellowstone River is used extensively for irrigation water, some enrichment may occur. Yet, the chemical analyses at Pierre, South Dakota, did not reflect any marked increase in mineral constituents of Missouri River water (Table 16).

Reservoirs vs. Rivers

The United States Geological Survey analyzed chemical samples from ten widely separated points in the Missouri River Basin during October 1950. The maximum total phosphorus expressed as PO_4 (0.677 ppm) was found in the James River at Huron, South Dakota, and the minimum (0.057 ppm) occurred in Angostura Reservoir near Hot Springs, South Dakota. The Missouri River at Pierre, South Dakota had 0.285 ppm and the South Platte River at Evans, Colorado, 0.225 ppm total phosphorus expressed as PO_4. The North Platte River and three of its reservoirs had total phosphorus (PO_4) concentrations ranging from 0.057 to 0.172 ppm (Table 17). The nitrogen values, especially ammonia nitrogen, were found to vary in concentration from station to station in about the same proportions as total phosphorus (PO_4).

Total phosphorus (PO_4) concentrations referred to above appear to be extremely low when compared to the 9.4--16.6 ppm maxima (page 46) found in the Missouri River between Sioux City, Iowa, and Council Bluffs, Iowa, during the same month of the year (October). Thus, low plankton productivity reported for the reservoirs (Table 14) might well be related to lack of nutrient enrichment (Table 17).

TABLE 17

Summary of Chemical Analyses Completed by the U. S. Geological Survey on the Missouri River Basin During October 1950

Station	Temp.	pH	NO_2	NO_3	NH_3	Phosphorus, ppm PO_4	
			(ppm Nitrogen)			Soluble	Total
Alcova Reservoir	56	7.8	0	0.10	.04	.021	.172
No. Platte R. Goose Egg, Wyo.	-	8.0	.003	.19	.05	.049	.116
No. Platte R. Cassa, Wyo.	53	8.1	.006	.46	.03	.012	.129
Guernsey Res.	52	7.9	.003	.25	.06	.021	.129
So. Platte R. Littleton, Col.	68	8.0	.006	.25	.09	.043	.067
So. Platte R. Evans, Col.	58	7.8	.030	1.64	.29	.141	.224
Angostura Res.	55	7.7	.003	.08	.01	.024	.058
James River	47	7.8	.040	.15	.42	.417	.677
Missouri River Pierre, S. Dak. B-11	46	7.9	0	.35	.03	.066	.285
Missouri River Yankton, S. Dak. B-3	53	7.8	.001	.9	0	.018	.245

It has long been recognized that inorganic nitrogen and phosphorous are nutritive materials necessary for algal growth. However, other factors such as sunlight, carbon dioxide, proper temperature, and pH are also necessary for growth and reproduction of algae in surface waters. The removal or alteration of any one factor can make it limiting. Thus, there exists a complicated or intricate operating design (environmental complex) common to each body of water that seldom is duplicated. Sawyer, et al, (1944) concluded rather generally that lakes having an average annual concentration of inorganic nitrogen (N) and phosphorous (P) in excess of 0.300 and 0.015 ppm, respectively, can be expected to produce frequent "nuisance blooms". The main stem of the Missouri River meets the prerequisites for the inorganic nitrogen and phosphorous south of Pierre, South Dakota. Obviously, turbidity and high current velocity are now operating as inhibiting factors in the main stem of the Missouri. Completion of the dams in progress could conceivably alter the environment to a condition where it would support algal growth in nuisance quantities.

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Nebraska State Department of Health
Lincoln, Nebraska

The chemical laboratories of the Nebraska State Health Department analyzed 95 samples from 13 stations between June 1 and August 29, 1950. The Station at Bellevue, Nebraska (2A) was a small creek tributary to the Missouri River and was often affected by backwater from it. Four stations (6A, 6B, 7A, and 7B) were in the Republican River Basin and the remainder were located on the Platte River between Lewellen and Ashland, Nebraska. The latter point is approximately 30 miles above confluence of the Platte and the Missouri Rivers. A summary of all analyses completed for each station comprises Appendix F.

The Platte River

A series of plankton samples collected from the Platte River (Table 11) already has established the Platte as a highly productive tributary to the Missouri River. The probable cause for the high plankton productivity is reflected in the increase in nutrient enrichment as shown in Table 18. Over approximately 340 miles of stream between Lewellen and Ashland, Nebraska, the ammonia nitrogen was noted to increase from 1.05 ppm to 1.42 ppm. Soluble phosphorus (PO_4) increased from .026 ppm to .87 ppm and total phosphorus (PO_4) from 1.30 ppm to 3.96 ppm. When compared to the 10.8 ppm concentration of total phosphorus (PO_4) found at Nebraska City, Nebraska, on the Missouri River (Table 19), the total phosphorus (PO_4) concentration of 3.96 ppm found at Ashland, Nebraska, is relatively low. Council Bluffs, Iowa, located above the mouth of the Platte River, also had a total phosphorus (PO_4) value above 10.0 ppm (Table 19). It would appear that most nutrients noted in the Missouri River were coming from sources other than the Platte.

The fact that the plankton drops from over 30,000 organisms per ml in the Platte River to 100 organisms per ml in the Missouri River seems to indicate that materials in solution alone do not insure high plankton productivity. It appears that unless waters rich in primary nutrient materials are accompanied by relatively low turbidity and current velocities they will not support plankton populations large enough to cause taste and odor problems.

Water Temperature

Platte River water temperatures recorded by the Nebraska State Health Department between Ashland and Lewellen, Nebraska, varied from 66° F (19° C) to 82° F (28° C) during June, July, and August 1950. The downstream change in water temperature during August was rather unusual in that 81° F (27.2° C) water was noted entering Lake McConaughy at Lewellen, Nebraska, while the Lake McConaughy surface water temperature immediately above the

TABLE 18

Summary of Chemical Analyses
of the Platte River during August 14 - 18, 1950
(Nebraska State Department of Health Laboratories)

Station	Mileage Point	Temp. (°F)	Turb.*	pH	NO_2 (ppm Nitrogen)	NO_3 (ppm Nitrogen)	NH_3 (ppm Nitrogen)	Phosphorus (ppm PO_4) Soluble	Phosphorus (ppm PO_4) Total
Lewellen, Neb.	369	81°	160	8.5	.004	Tr	1.05	0.026	1.30
Lake McConaughy	344	75°	-25	8.5	.012	Tr	1.09	0.024	1.32
Columbus, Neb.	100	73°	810	8.1	.012	Tr	1.42	0.87	2.80
Ashland, Neb.	30	-	2100	8.0	.001	Tr	1.28	0.78	3.96

* "-25" indicates "Less than 25".

TABLE 19

Chemical Analyses of the Missouri River at Four Stations
and the Platte River at Ashland, Nebraska, on or about August 15, 1950
(State Hygienic Laboratory, Iowa City, Iowa)

Station	Mileage Point	Temp. (°F)	Turb.	pH	NO_2 (ppm Nitrogen)	NO_3 (ppm Nitrogen)	NH_3 (ppm Nitrogen)	Phosphorus (ppm PO_4) Soluble	Phosphorus (ppm PO_4) Total
Sioux City, Iowa	760	79°	900	8.2	.005	.41	.001	0.15	6.25
Whiting, Iowa	732	79°	700	8.0	.006	.38	.08	0.20	7.3
Council Bluffs, Iowa	635	-	1000	8.1	.003	.37	.06	0.19	10.4
Platte River Ashland, Neb.*	30	-	2100	8.0	.001	Tr	1.28	0.78	3.96
Nebraska City, Neb.	579	76°	1000	7.9	.011	.44	.53	0.23	10.8

*Nebraska State Department of Health Laboratories

dam was only 75° F (23.9° C). At Columbus, Nebraska, over 240 miles below Lake McConaughy, the water temperature was 73° F (22.8° C). The apparent temperature decline of the Platte River water as it moved downstream was undoubtedly the result of an abrupt decrease in temperature which occurs at the outlet of Lake McConaughy (Kingsley Dam). On August 15, 1950, a water temperature of 72° F (22.2° C) was found above the dam while the water leaving the lake below the dam was only 58° F (14.4° C) (Table 12). Such a change certainly must have a marked effect on the water temperature of the Platte River as well as on the mineral content. The resulting maxima and minima of nitrogen and phosphorus concentrations between June and August 1950, comprise Table 20. The total phosphorus (PO_4) at Columbus, Nebraska, showed the greatest variation (8.8 ppm) from a minimum of 0.60 ppm to a maximum of 9.4 ppm

TABLE 20

The maxima and minima of nitrogen and phosphorus (PO_4) concentrations in ppm as reported by the Nebraska State Health Department for the Platte River from June through August 1950

Station	Mileage Point	NO_2 (ppm Nitrogen)	NO_3 (ppm Nitrogen)	NH_3 (ppm Nitrogen)	Phosphorus (ppm PO_4) Soluble	Phosphorus (ppm PO_4) Total
Lewellen, Neb.	369	.002-.07	Tr	.20-1.08	Tr-.252	.33-6.3
Lake McConaughy	344	.003-.012	Tr	.44-1.14	Tr-.156	.20-4.84
Columbus, Neb.	100	Tr -.046	Tr	.04-1.98	.28-.96	.60-9.4
Ashland, Neb.	30	0-.014	Tr	.02-1.32	.22-.78	1.6-8.5

DISCUSSION

The nature of this plankton study, made in the form of a reconnaissance, obviously did not allow very detailed observations in any one area; and positive results are not necessarily expected. However, despite this limitation, the data indicate certain conditions that might well be generally applicable. First, there is a year-round dearth of plankton organisms in the Missouri River below Fort Peck Reservoir. Second, considerable concentrations of nitrogen and phosphorus occur in the Missouri River between Yankton, South Dakota, and Nebraska City, Nebraska, (Table 16); and lack of primary nutrient minerals, therefore, may not be held accountable for low plankton productivity. Third, it has been indicated that turbidity combined with high current velocities are factors responsible for lack of plankton productivity (Berner, 1951). Data presented herein seem to support such a contention. Fourth, it would seem that construction of Fort Randall Dam above Yankton, South Dakota, would reduce turbidity and high current velocity in the impounded area of the Missouri and permit development of plankton populations which may cause damage during certain seasons to domestic supplies taken from the reservoir. Fifth, periods of taste and odor problems may then develop at intervals along the course of the Missouri River at undetermined distances below the dam, whenever reduced turbidity and stream velocity will permit the development of large plankton populations.

Observations made and data collected relating to the effect of impoundments on plankton productivity in the Missouri River Basin revealed at first what appeared to be most contradictory results. It would seem natural to assume that the removal of the turbidity usually occurring in an impoundment would result in an increase in plankton productivity because of the increase in solar radiation which would follow. On the contrary, plankton productivity was noted to decrease <u>in</u> and increase <u>below</u> the six reservoirs sampled in Montana, South Dakota, and Wyoming (Table 14). However, nutrients (phosphorus (PO_4) and nitrate nitrogen), so characteristic of the Missouri and Platte Rivers, were low in the reservoirs by comparison (Tables 17, 18, and 19) and thus appeared to be the limiting factors. These results support well the contention of Tarzwell and Palmer (1951) that reservoir sites should be selected where the soil is poor and the sides of the reservoir are steep in order to prevent nutrient enrichment by runoff water or the development of flats and shallow bays. Neel (1951) contends that the increase in plankton productivity below reservoirs results because of the nutrients which were produced by the oxidation of anaerobic compounds. The oxidation produces nitrates and phosphates from the hypolimnion water which is discharged. Surface water was released from the Alcova Reservoir and the plankton were noted to decrease in the river below the impoundment.

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APPENDIX A

LIST OF PLANKTON SAMPLES

COLLECTED IN THE MISSOURI RIVER BASIN SURVEY

SUMMER, 1950

By

Kenneth E. Damann
Special Consultant

Federal Security Agency
Public Health Service
Environmental Health Center

APPENDIX A (Cont.)

MISSOURI RIVER BASIN PLANKTON SUMMARY
OF SAMPLES COLLECTED DURING
JUNE, JULY, AUGUST, AND SEPTEMBER, 1950

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. Per ml.	Predominate Organisms
1	Missouri River	Kansas City	6/29	0	
2	Kansas R.	Lawrence, Kans.	6/30	170	Navicula Scenedesmus
3	Kansas R.	Topeka, Kans.	7/2	380	Navicula Scenedesmus
3A	Kansas R.	Topeka, Kans.	7/1	600	Navicula Euglena
4B	Holton Lake 3 meters	Holton, Kans.	7/3	700	Oocystis Mallomonas
4C	Holton Lake surface	Holton, Kans.	7/3	420	Oocystis Mallomonas
4D	Holton Lake	Holton, Kans.	8/21	1,240	Oocystis Mallomonas
5D	Horton Water Plant	Horton, Kans.	7/5	80	Trachelomonas Rhodomonas
5E	Horton Water Intake	Horton, Kans.	8/23	110	Monas
5(1)	Mission L., North	Horton, Kans.	7/4	1,840	Trachelomonas
5F	Mission L., North	Horton, Kans.	8/23	330	Rhodomonas
5	Mission Lake	Horton, Kans.	7/4	60	Trachelomonas
5X	Mission Lake	Horton, Kans.	7/4	140	Monas
6	Missouri River	Rulo, Nebr.	7/5	40	Navicula Trachelomonas
7	Missouri R.	Nebraska City	7/6	100	Navicula Trachelomonas
8	Platte R.	Fremont, Nebr.	7/7	2,520	Navicula Actinastrum
9	Missouri R.	Sioux City, Ia.	7/8	300	Navicula

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
10	Big Sioux R.	N.Sioux City, Ia.	7/8	24,260	Stephanodiscus Cyclotella Actinastrum
10A(1)	Big Sioux R.	N.Sioux City, Ia.	7/11	24,460	Actinastrum Cyclotella Stephanodiscus
10B	Big Sioux R.	Near Riverside Power Plant	7/11	22,580	Actinastrum Cyclotella Stephanodiscus
10C	Big Sioux R.	Below Sioux Falls, South Dakota	7/15	66,320	Cyclotella Actinastrum
10C(1)	Big Sioux R.	Above Sioux Falls, S. Dak.	7/15	44,160	Cyclotella Actinastrum
10D	Big Sioux R.	Inwood, Iowa	7/15	71,560	Actinastrum Cyclotella Stephanodiscus
10E	Big Sioux R.	Westfield, Iowa	7/15	86,960	Actinastrum Cyclotella Stephanodiscus
10F	Big Sioux River Mouth	No.Sioux City, Iowa	7/15	22,280	Actinastrum Cyclotella
10G	Missouri R.	Below Mouth of Big Sioux R.	7/15	2,320	Cyclotella Stephanodiscus
10H	Missouri R.	Elk Point, So. Dak.	7/15	600	Aphanizomenon Monas
11	Vermillion R.	Vermillion, S.Dak., Rt. 50	7/8	21,240	Synedra Actinastrum
11(1)	Vermillion R.	Vermillion, S.D., Rt. 50	7/11	21,520	Actinastrum Synedra Cyclotella
11B	Missouri R.	Above Vermillion Mouth	7/12	480	Aphanizomenon
11C	Missouri R.	Below Vermillion R.Mouth	7/12	2,400	Cyclotella Aphanizomenon Nitzchia Monas

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
11D	Vermillion R.	At mouth	7/12	64,520	Nitzchia Cyclotella Actinastrum Monas
11E	Vermillion R.	1/2 mile above mouth	7/12	38,360	Nitzchia Cyclotella Actinastrum Monas
11F	Vermillion R.	3 miles above mouth	7/12	21,080	Nitzchia Cyclotella Actinastrum Monas
11G	Vermillion R.	20 miles above mouth	7/12	26,040	Navicula Nitzchia Cyclotella Actinastrum Monas
11H	Vermillion R.	38 miles above mouth	7/12	18,240	Scenedesmus Nitzchia Cyclotella Astinastrum Monas
11J	Vermillion R.	Vermillion, S.D., Rt. 50	7/15	20,680	Cyclotella Nitzchia Actinastrum
11K	Vermillion R.	Rt.16, west of Sioux Falls		36,040	Cyclotella Nitzchia Actinastrum
12	James R.	Rt.50, near Yankton, S.D.	7/8	7,700	Aphanizomenon
12(1)	James R.	Rt.50, near Yankton, S.D.	7/11	7,696	Aphanizomenon
12C	James R.	At mouth	7/13	29,160	Aphanizomenon
12D	James R.	Rt.50, Yankton, S.D.	7/13	25,400	Aphanizomenon Actinastrum Cyclotella

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
12E	James R.	Rt.81, north of Yankton	7/12	21,200	Aphanizomenon Actinastrum Cyclotella
12F	James R.	Rt.18, Olivet,S.D.	7/12	23,840	Aphanizomenon Actinastrum Cyclotella
12G	James R.	East of Huron,S.D.	7/16	12,720	Aphanizomenon Cyclotella
12H	James R.	Forestburg, S. D.	7/16	20,000	Aphanizomenon Cyclotella Actinastrum
12J	James R.	Mitchell,S.D.	7/17	26,760	Aphanizomenon Cyclotella Actinastrum
12K	James R.	Jamestown,N.D.	7/26	21,360	Aphanizomenon Cyclotella Synedra
13	Missouri R.	Yankton,S.D., water plant bridge	7/9	120	Monas
13C	Missouri R.	Yankton,S.D.	7/14	120	Monas
14	Lake Andes	Lake Andes,S.D.	7/9	140	Navicula Sphaerocystis
15	Missouri R.	Ft.Randall Dam	7/9	20	Monas
16A	Lake Mitchell (surface)	Lake Mitchell, S. D.	7/16	8,760	Aphanizomenon
16B	Lake Mitchell (9 ft.depth)	Lake Mitchell, S. D.	7/16	50	Stephanodiscus
16C	Lake Mitchell (18 ft.depth)	Lake Mitchell, S. D.	7/16	120	Stephanodiscus
16D	Lake Mitchell (north end)	Lake Mitchell S. D.	7/16	3,400	Aphanizomenon
16E	Lake Mitchell	Water intake	7/17	9,180	Aphanizomenon

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
16F	Lake Mitchell	Eight ft. depth	7/17	1,140	Aphanizomenon
16G	Lake Mitchell	Water intake, surface	7/18	520	Aphanizomenon
17	Missouri R.	Chamberlain, S.D., Rt. 16 bridge	7/19	160	Navicula Cyclotella Monas
17A	Missouri R.	Chamberlain water intake	7/19	240	Navicula Cyclotella Monas
18	Bad R.	Pierre, S.D.	7/19	7,800	Synedra Actinastrum Beggiatoa
19	Missouri R.	Pierre, S.D.	7/19	520	Navicula
20	Missouri R.	Whitlock, S.D.	7/19	400	Navicula Actinastrum
21	Missouri R.	Mobridge, S.D.	7/20	400	Navicula
21A	Missouri R.	Mobridge water intake	7/20	360	Navicula
22	Grand R.	Mouth at Mobridge, S.D.	7/20	9,040	Diatoms: Synedra, Navicula
22B	Grand R.	North of Mobridge, S.D.	7/21	3,360	Diatoms: Synedra, Navicula
23	Cannonball R.	Rt. 6, So. of Bismarck	7/21	4,640	Diatoms: Synedra, Navicula
24	Heart R.	Rt. 6, So. of Bismarck	7/21	2,000	Synedra
25	Missouri R.	Bismarck water plant	7/22	70	Navicula Tribonema Trachelomonas
26	Missouri R.	Garrison Dam	7/22	560	Navicula

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
27	Riviere des Lacs	Near Foxholm, N. D.	7/22	102,500	Aphanizomenon
28A	Lake Darling	Above dam opening	7/23	24,750	Aphanizomenon
28B	Lake Darling	Below dam opening	7/23	25,600	Aphanizomenon
29A	Lower Des Lacs Lake	Kenmare, N.D.	7/24	62,000	Aphanizomenon
29B	Middle Des Lacs Lake	Kenmare, N.D.	7/24	21,200	Microcystis
29C	Entrance to middle Des Lacs	Kenmare, N.D.	7/24	23,520	Microcystis
29D	Upper Des Lacs Lake	Rt.52 bridge	7/24	25,040	Microcystis
29E	Des Lacs Head Water	Saskatchewan, Canada	7/24	17,480	Microcystis
30	Little Muddy Creek	No.of Williston, N. D.	7/25	320	Navicula
31	Heart R.	Dickinson Dam	7/28	3,320	Cyclotella Navicula Anabaena Aphanizomenon
32	Little Missouri R.	So.of Williston, N. D.	7/28	24,040	Cyclotella Synedra Actinastrum
32B	Little Missouri R.	Alzada, Mont.	8/6	540	Diatoms Flagellates
33	Missouri R.	Williston, N.D.	7/29	640	Diatoms Flagellates
34	Missouri R.	W.of Williston, N. D.	7/30	1,200	Diatoms Flagellates
35	Missouri R.	East of Yellowstone R. mouth	7/31	200	Navicula Synedra

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
36	Yellowstone R.	Fairview,Mont.	7/31	480	Navicula
36A	Yellowstone R.	Irrigation ditch near Fairview, Mont.	7/31	200	Navicula
36C	Yellowstone R.	Glendive,Mont.	8/5	400	Navicula
36D	Yellowstone R.	Fallon,Mont.	8/5	640	Navicula Monas
36E	Yellowstone R.	Miles City,Mont.	8/6	1,200	Navicula Monas
37	Missouri R.	Snowden,Mont.	7/31	440	Navicula
38	Big Muddy Creek	Culbertson,Mont.	7/31	4,400	Cyclotella Navicula Synedra Monas
39	Poplar R.	Poplar,Mont.	8/1	640	Navicula
40	Milk R., shore	Nashua,Mont.	8/1	4,560	Actinastrum
40B	Milk R. bridge	Nashua,Mont.	8/4	2,480	Actinastrum Synedra
41	Ft.Peck Res. (above spillway)	Ft.Peck,Mont.	8/1	160	Navicula Monas
41B(1)	Ft.Peck Reservoir	Surface above dam	8/2	100	Monas Rhodomonas
41B(2)	Ft.Peck Reservoir	3 M depth	8/2	10	Rhodomonas
41B(3)	Ft.Peck Reservoir	10 M depth	8/2	0	
41B (3')	Ft.Peck Reservoir	20 M depth	8/2	0	
41C	Ft.Peck Res.	Below power plant	8/3	170	Navicula
41D(2)	Ft.Peck Res.	South dredged area	8/3	720	Rhodomonas

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
41D(2)	Ft.Peck Res.	Raw tap at filtration plant	8/3	100	Diatoms
42	Wolf Creek	Wolf Point,Mont.	8/4	1,420	Diatoms Actinastrum
43	Missouri R.	So.of Wolf Point,Mont.	8/4	220	Diatoms Flagellates
44	Red Water Creek	Circle,Mont.	8/5	180	Diatoms Ciliates
45	Fallon Creek	Fallon,Mont.	8/5	1,920	Navicula Synedra Monas
46	Powder R.	Terry,Mont.	8/6	1,800	Synedra Actinastrum Monas
46B	Powder R.	Broadus,Mont.	8/6	14,200	Synedra Cyclotella Actinastrum
47	Tongue R.	Miles City,Mont.	8/6	360	Navicula
48	Belle Fourche Reservoir	Belle Fourche,SD, near dam	8/8	30	Diatoms Flagellates Crustacea
48(1)	Belle Fourche Reservoir	Center of reservoir	8/8	20	Diatoms Flagellates Crustacea
48B	Belle Fourche Reservoir	North end	8/8	20	Diatoms Flagellates Crustacea
48D	Belle Fourche River	Belle Fourche, S. D.	8/8	7,880	Diatoms Rhodomonas Monas
49	Spearfish Dam	Spearfish,S.D.	8/8		Diatoms Flagellates
50	Sylvan Lake	Black Hills,S.D.	8/9	720	Anabaena

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
51	Deerfield Res.	Deerfield, S.D.	8/10	820	Microcystis
51B	Deerfield Creek	Below dam	8/10	1,020	Diatoms
52	Angostura Dam	Hot Springs, S. D.	8/11	140	Diatoms Flagellates
53	Cheyenne R.	Hot Springs, S. D.	8/11	610	Diatoms
54	North Platte R.	Guernsey, Wyo.	8/12	930	Diatoms
55A	Guernsey Res.	Surface sample	8/12	1,050	Diatoms Rhodomonas Monas
55B	Guernsey Res.	2-1/2 M. deep	8/12	630	Rhodomonas Monas
55C	Guernsey Res.	5 M. deep	8/12	520	Rhodomonas Monas
55D	Guernsey Res.	10 M. deep	8/12	400	Fragilaria
55E	Guernsey Res.	15 M. deep	8/12	630	Diatoms Monas
56	No.Platte R.	Douglas, Wyo.	8/13	600	Diatoms
56A	No.Platte R.	Scottsbluff, Nebr.	8/14	2,860	Diatoms
56B	No.Platte R.	Bridgeport, Nebr.	8/14	3,320	Diatoms
56C	No.Platte R.	Lewellen, Nebr.	8/14	8,640	Diatoms
57	LaPrele Res.	LaPrele, Wyo.	8/13	780	Navicula
58	Blue Grass Creek	Wheatland, Wyo.	8/13	460	Navicula Melosira
59	Laramie R.	Wheatland Wyo.	8/13	2,020	Navicula
60	Lake McConaughy, surface	Ogallala, Nebr.	8/15	550	Fragilaria

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APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1959	Plankton Results	
				Total No. per ml.	Predominate Organisms
60A	Lake McConaughy	5 M. deep	8/15	5,170	Fragilaria
60B	Lake McConaughy	10 M. deep	8/15	3,460	Fragilaria
60C	Lake McConaughy	26 M. deep	8/15	320	Fragilaria
60D	Lake McConaughy	Below dam	8/15	690	Fragilaria
61	South Platte R.	Ogallala, Nebr.	8/15	3,860	Navicula Synedra
62	Frenchman R.	Enders Dam	8/16	1,160	Navicula
63	South Fork Solomon R.	Hill City, Kans.	8/17	660	Monas
64	Big Creek	Yocemento, Kans.	8/18	360	Monas
65	Smoky Hill R.	Ellsworth, Kans.	8/18	300	Monas
66	Kanapolis Res.	Below spillway	8/19	80	Monas
66X	Kanapolis Res.	Marina Dock	8/19	100	Protozoa
66A	Kanapolis Res.	Opposite control tower	8/20	1,155	Aphanizomenon
66B	Kanapolis Res.	North end of dam	8/20	150	Aphanizomenon Microcystis
66C	Kanapolis Res.	Horseshief Cove	8/20	350	Aphanizomenon
66D	Kanapolis Res.	Yankee Cove	8/20	230	Aphenizomenon
66E	Kanapolis Res.	South of Lapham Point	8/20	150	Aphanizomenon Monas
66F	Kanapolis Res.	Langley Point	8/20	1,570	Aphanizomenon Microcystis
66G	Kanapolis Res.	Surface sample	8/20	430	Microcystis
66H	Kanapolis Res.	5 M. sample	8/20	110	Monas
66I	Kanapolis Res.	10 M. sample	8/20	50	Monas

APPENDIX A (Cont.)

Sample No.	Source	Location	Date 1950	Plankton Results	
				Total No. per ml.	Predominate Organisms
67	Saline River	Salina, Kans.	8/20	130	Monas
68	Solomon R.	Salina, Kans.	8/20	70	Monas
69	Republican R.	Junction City, Kans.	8/21	30	Monas
70	Platte R.	Farley, Mo.	8/24	220	Diatoms
71	Sheyenne R.	Valley City, N.D.	7/26	2,200	Aphanizomenon
72	Sheyenne R.	Fargo, N.D.	7/26	340	Diatoms
73	Red R.	So. of Fargo, N. D.	7/26	1,680	Stephanodiscus
74	Red R.	Grand Forks, N.D.	7/26	260	Stephanodiscus
75	Red Lake R.	E. Grand Forks	7/26	1,720	Actinastrum Synedra Navicula
77	Missouri R.	Kansas City, Mo.	8/24	60	Melosira Navicula
78	Missouri R.	Jefferson City, Mo.	8/25	80	Navicula Gyrosigma
79	Moreau R.	Jefferson City, Mo.	8/25	2,940	Diatoms Green Algae
80	Osage R.	Osage City, Mo.	8/25	140	Diatoms
81	Gasconade R.	Mt. Sterling, Mo.	8/25	200	Diatoms
82	Missouri R.	St. Louis County Water Co.	8/26	160	Diatoms
83	Mississippi R.	Chain of Rocks Bridge, St. Louis, Mo.	8/25	140	Diatoms
84	Pathfinder Res.	Wyoming	7/8	413	Diatoms
85	Pathfinder Res.	Wyoming	7/8	400	Diatoms
86	Alcova Res.	Wyoming	7/9	14	Diatoms

APPENDIX A (Concluded)

Sample No.	Source	Location	1950 Date	Plankton Results	
				Total No. per ml.	Predominate Organisms
87	No.Platte R.	Keystone,Nebr.	9/15	1,860	Diatoms
88	So.Platte R.	Ogallala,Nebr.	9/15	3,600	Diatoms
89	No.Platte R.	Sutherland,Nebr.	9/15	6,120	Diatoms
90	So.Platte R.	Hershey,Nebr.	9/15	3,240	Diatoms
91	Platte R.	Maxwell,Nebr.	9/15	5,040	Diatoms
92	Platte R.	Gothenburg,Nebr.	9/15	2,060	Diatoms
93	Platte R.	Lexington,Nebr.	9/15	3,080	Diatoms
94	Platte R.	Kearney,Nebr.	9/15	3,040	Diatoms
95	Platte R.	Wood River,Nebr.	9/15	4,920	Diatoms
96	Platte R.	Columbus,Nebr.	9/15	7,880	Diatoms
97	Platte R.	North Bend,Nebr.	9/15	17,320	Diatoms
98	Platte R.	Leshara,Nebr.	9/15	20,760	Diatoms Scenedesmus
99	Platte R.	Ashland,Nebr.	9/15	30,080	Diatoms Scenedesmus
100	Platte R.	Oreapolis,Nebr.	9/15	31,320	Diatoms Scenedesmus

APPENDIX B

Masters Degree Thesis Titles on Limnology
Kansas State Teachers College

A list of titles of Master's theses supplied by Theodore M. Sperry, Kansas State Teachers College, Manhattan, Kansas, in a letter dated June 26, 1950.

1.	Anderson, J. N.	Limnological Study of Tar Creek
2.	Bailey, L. L.	Survey of Filamentous Green Algae of Labette County, Kansas Trans. Kan. Acad. Sci. 35: 1932
3.	Collins, A. B.	Limnological Study of College Lake
4.	Fry, K. A.	Fauna of Cow Creek
5.	Leonard, Ed	Helminth Parasites of Centrarchid Fishes of Strip Pits of Crawford County, Kansas
6.	Mannoni, S. A.	Survey of the Green Algae of Crawford County, Kansas Trans. Kan. Acad. Sci. 35: 1932
7.	Sherman, T.	Algae of College Lake
8.	Stevens, R. E.	Fishes of Cherokee County
9.	Willson, D. L.	Studies on Algal-Bacterial Associations

APPENDIX C

Chemical Analyses of Fort Peck, Montana, Reservoir Water
by the Corps of Engineers, Fort Peck, Montana,
During August 1948

Sampling points were as follows:

Mile	Surface Sample	Deep Sample (Depth in feet)
1	X	190
18	X	90
37	X	90
74	X	70
92	X	45

Note: In table for Appendix C, figures for nitrate expressed as ppm nitrogen (nitrate nitrogen) may be determined by dividing the figures for "Nitrate (NO_3) ppm" listed on page 72 by the factor 4.43.

APPENDIX C (Cont.)

Chemical Analyses of Fort Peck Reservoir Wate
During August 1948

Laboratory Number	K-7805	K-7806	K-7807	K-7808	K-7809	K-7810
Field Sample Number	1	2	3	4	5	6
Date Sampled	8-16-48	8-16-48	8-17-48	8-17-48	8-18-48	8-18-48
Depth of sample (feet)	Surface	90.0	Surface	90.0	Surface	70.0
Field Log	Mile 18 - Range 1 W.S.2241.07	Mile 18 - Range 1 W.S.2241.07	Mile 37 - Range 2 W.S.2240.94	Mile 37 - Range 2 W.S.2240.94	Mile 74 - Range 26 W.S.2240.82	Mile 74 - Range 26 W.S.2240.82
Analysis:						
Suspended solids, ppm	0	1	2	6	33	14
Dissolved solids (Residue at 103° C.), ppm	379	448	363	436	377	397
Alkalinity to phenolphthalein (as $CaCO_3$), ppm	0.0	0.0	0.0	0.0	0.0	0.0
Alkalinity to methyl orange (total alkalinity, as $CaCO_3$), ppm	123	131	119	136	130	134
Total hardness (as $CaCO_3$), ppm	153	165	152	163	171	166
Calcium (Ca), ppm	51	56	51	55	58	56
Magnesium (Mg), ppm	6.1	6.1	6.0	6.2	6.3	6.3
Alkalies (as Na), ppm	61	79	52	75	62	57
Iron (Fe), ppm	0.15	0.10	0.14	0.15	0.13	0.15
Manganese (Mn), ppm	0.00	0.00	0.00	0.00	0.00	0.00
Sulfate (SO_4), ppm	143	184	132	170	160	138
Chloride (Cl), ppm	8.7	8.5	5.5	8.5	4.9	7.4
Nitrate (NO_3), ppm	0.7	1.9	1.0	2.2	0.8	2.5
Bicarbonate (HCO_3), ppm	150	160	145	166	159	163
Carbonate (CO_3), ppm	0.0	0.0	0.0	0.0	0.0	0.0
Silica (SiO_2), ppm	12	11	11	12	11	16
pH	7.8	8.0	7.7	8.1	8.1	7.7

APPENDIX C (Cont.)

mical Analyses of Fort Peck Reservoir Water
During August 1948

807	K-7808	K-7809	K-7810	K-7811	K-7812	K-7813	K-7814
3	4	5	6	7	8	9	10
7-48	8-17-48	8-18-48	8-18-48	8-18-48	8-18-48	8-21-48	8-21-48
face	90.0	Surface	70.0	Surface	45.0	Surface	190.0
e 37 - ge 2 2240.94	Mile 37 - Range 2 W.S.2240.94	Mile 74 - Range 26 W.S.2240.82	Mile 74 - Range 26 W.S.2240.82	Mile 92 - Range 3 W.S.2240.73	Mile 92 Range 3 W.S.2240.73	Mile 1 W.S.2240.26	Mile 1 W.S.2240.26
2	6	33	14	9	4	0	0
3	436	377	397	398	553	395	461
0.0	0.0	0.0	0.0	0.0	2.4	1.3	0.0
9	136	130	134	144	135	123	133
	163	171	166	176	200	155	167
1	55	58	56	60	70	52	57
6.0	6.2	6.3	6.3	6.4	6.2	6.0	6.0
2	75	62	57	57	90	59	59
0.14	0.15	0.13	0.15	0.15	0.14	0.25	0.15
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	170	160	138	141	244	143	142
5.5	8.5	4.9	7.4	4.4	5.3	7.4	3.7
1.0	2.2	0.8	2.5	5.2	1.3	1.2	1.2
5	166	159	163	176	159	148	162
0.0	0.0	0.0	0.0	0.0	1.4	0.8	0.0
11	12	11	16	10	9.4	19	6.6
7.7	8.1	8.1	7.7	7.0	8.4	8.3	7.9

APPENDIX D

Chemical Analyses Completed on the Missouri River
by the State Hygienic Laboratory, Iowa City, Iowa,
for the Period July 1950 to January 1951.

Sampling points were as follows:

760 mile point - Sioux City, Iowa
Missouri River at Combination Bridge

732 mile point - Whiting, Iowa
Missouri River at Olson Landing

635 mile point - Council Bluffs, Iowa
Missouri River at Waterworks Intake

579 mile point - Nebraska City, Nebraska
Missouri River at Highway Bridge

APPENDIX B (Cont.)

CHEMICAL ANALYSES FOR

SIOUX CITY, MISSOURI RIVER AT COMBINATION BRIDGE

760 Mile Point

All results in parts per million, unless otherwise noted

1950	7/19	8/2	8/16	9/6	9/21	10/4	10/18	11/1	11/15	12/6	12/20	1/5/51
Temp. at Collection (°F)	68	73	79	70	64	50	60	52	38	32	-	32
Turbidity (Jackson)	1300	800	900	700.	750.	1000	750	550	680.	63	115.	190.
Alkalinity (As $CaCO_3$) P	2.	6	4	6.0	5.0	4.0	10.0	1.0	8.0	7	6.0	4.0
Alkalinity (as $CaCO_3$) T	90.	102	104	140.	134.	142.	146.0	152.	154.	200	212.	184.
pH	6.4	8.1	8.2	8.58	7.8	8.2	8.3	8.1	8.0	8.1	8.1	7.98
Calcium (Ca)	38.0	40.0	45.5	55.4	57.4	58.4	60.4	60.4	60.4	82.2	83.1	75.2
Magnesium (Mg)	11.0	15.0	11.5	17.7	17.2	16.5	20.4	18.4	19.7	25.3	27.9	25.1
Chloride (Cl)	7.0	8.0	5.0	12.0	12.	11.	10	10.0	10.0	18	15.	13.0
Sulfate (SO_4)	108.0	104.0	147.9	159.7	173.	192.	199.4	190.5	183.9	191.8	251.	223.7
Silica (SiO_2)	8.0	11.0	12.0	12.0	11	12.0	11.0	9.5	7.5	-	16.0	14.0
Phosphorous Soluble (PO_4)	0.11	0.19	0.15	0.30	0.23	0.22	0.35	0.075	0.075	-	0.175	0.94
Phosphorous Total (PO_4)	6.35	4.62	6.25	6.65	6.65	9.3	9.4	1.25	1.90	-	2.00	1.80
Sodium and Potassium (as Na)	44.0	40.0	50.0	53.9	55.2	61.	60.4	59.7	59.1	57.1	37.3	71.7
Total Organic Nitrogen (N)	6.80	3.78	2.34	3.26	0.70	1.21	0.28	0.67	0.85	1.26	0.61	1.54
Ammonia Nitrogen (N)	0.08	0.02	-0.001	0.01	0.027	0.001	0.0093	0.001	0.001	0.23	0.015	0.001
Nitrite Nitrogen (N)	0.006	0.006	0.005	0.005	0.0046	0.004	0.0246	0.020	0.011	0.013	0.028	0.022
Nitrate Nitrogen (N)	0.50	0.45	0.41	0.2	0.22	0.57	0.53	0.56	0.69	0.90	0.64	0.61

CHEMICAL ANALYSES FOR
WHITING. MISSOURI RIVER AT OLSON LANDING
732 Mile Point

1950	7/19	8/2	8/16	9/6	9/21	10/4	10/18	11/1	11/15	12/6	12/20	1/5/51
Temp. at Collection (°F)	69	72	79	-	64	50	60	52	38	38	32	32
Turbidity (Jackson)	1200	900	700	700.	600	1400	700	525.	750.	600	100.	170.
Alkalinity (as $CaCO_3$) P	4	6	4	6.0	6.0	8.0	8.0	2.0	8.0	3	10.0	5.0
Alkalinity (as $CaCO_3$) T	104.	106	114	134.	136	138.	146.0	152.	154.	210	212.	186.
pH	8.4	8.1	8.0	8.6	8.0	8.3	8.3	8.1	8.1	7.95	8.15	7.9
Calcium (Ca)	40.0	40.0	48.5	59.4	56.4	57.4	63.4	58.4	60.4	82.2	84.2	70.3
Magnesium (Mg)	11.0	12.0	12.9	17.4	16.9	16.1	19.3	17.6	18.3	26	28.1	25.8
Chloride (Cl)	10.0	8.0	12.0	13.0	11.	11.	11.0	12.0	10.0	15.	17.	14.5
Sulfate (SO_4)	120.0	106.0	139.9	167.1	175.9	192.7	196.9	192.2	183.9	198.8	253.9	229.
Silica (SiO_2)	8.0	11.0	11.3	12.0	12	12.0	10.0	8.7	7.0	-	15.0	14.0
Phosphorous Soluble (PO_4)	0.14	0.22	0.20	0.17	0.17	0.21	0.31	0.13	0.16	-	0.20	0.125
Phosphorous Total (PO_4)	5.83	6.38	7.3	5.20	5.20	9.4	8.7	1.90	1.90	-	2.00	1.30
Sodium & Potassium (as Na)	47.0	40.0	51.3	59.7	55.2	59.7	61.7	59.7	61.	60.3	87.3	73.3
Total Organic Nitrogen (N)	7.70	3.92	2.52	1.68	0.87	1.59	0.69	1.11	1.06	1.71	0.84	2.04
Ammonia Nitrogen (N)	0.04	0.06	0.08	0.01	0.01	0.001	0.001-	0.001	0.033	0.17	0.084	0.08
Nitrite Nitrogen (N)	0.002	0.006	0.006	0.0015	0.0050	0.003	0.0064	0.020	0.010	0.011	0.012	0.013
Nitrate Nitrogen (N)	0.50	0.41	0.38	0.2	0.22	0.80	0.61	0.68	0.53	0.74	0.61	0.54

APPENDIX D (Cont.)

CHEMICAL ANALYSES FOR
COUNCIL BLUFFS, MISSOURI RIVER WATERWORKS INTAKE
635 Mile Point

All results in parts per million.

1950	7/19	8/2	8/16	9/6	9/20	10/4	10/18	11/1	11/15	12/5	12/20	1/3/51
Temp. at Collection °	73	76	68	-	68	58	57	58	44	34	36	34
Turbidity (Jackson)	1000	1000	1000	750.	650	1700	750	650.	780.	120	75.	160
Alkalinity (As $CaCO_3$)P	4	2	4	8.0	10	10.	8.0	4.0	6.0	6	6.0	4.0
Alkalinity (As $CaCO_3$) T	102	102	104	144.	146	138	146.0	156.	154.	223	224.	198.
pH	8.4	7.9	8.1	8.6	8.0	8.3	8.2	8.1	8.09	7.9	8.2	7.9
Calcium (Ca)	40.0	42.-	45.4	59.4	60.4	58.4	61.4	54.9	59.4	82.2	92.	67.3
Magnesium (Mg)	10.0	13.0	11.7	17.6	13.1	16.6	19.0	17.3	19.2	28.5	29.5	26.5
Chloride (Cl)	8.0	8.0	4.0	12.0	11	11.	11.0	11.0	11.0	17	19.	14.0
Sulfate (SO_4)	147.0	106.0	133.9	157.2	175.7	180.9	194.0	193.	192.7	236.4	262.9	229.6
Silica (SiO_2)	10.0	12.0	12.0	12.5	12	12.5	10.5	9.0	8.0	-	14.5	15.0
Phosphorous Soluble (PO_4)	0.20	0.18	0.19	0.17	0.15	0.275	0.215	0.15	0.075	-	0.175	1.00
Phosphorous Total (PO_4)	8.50	7.7	10.4	5.20	4.15	16.6	8.9	2.50	1.90	-	1.30	3.40
Sodium & Potassium (as Na)	42.0	38.0	45.4	59.7	55.2	61.7	60.4	61.7	58.7	69.8	87.6	71.7
Total Organic Nitrogen (N)	4.20	2.66	2.8	1.40	0.84	2.42	0.79	0.82	1.23	0.08	0.37	1.62
Ammonia Nitrogen (N)	0.04	0.11	0.06	0.01	0.01	0.001	0.001-	0.001	0.040	0.085	0.13	0.06
Nitrite Nitrogen (N)	-0.001	0.003	0.006	0.0008	0.0032	0.0028	0.0064	0.0046	0.013	0.011	0.010	0.011
Nitrate Nitrogen (N)	0.40	0.54	0.37	0.2	0.22	0.61	0.61	0.54	0.60	0.53	0.61	0.56

APPENDIX D (Con't)

CHEMICAL ANALYSES FOR

NEBRASKA CITY. MISSOURI RIVER AT HIGHWAY BRIDGE

579 Mile Point

1950	7/19	8/2	8/16	8/30	9/18	9/27	10/11	10/25	11/8	11/22	12/6	12/20	1/3/51
Temp. at Collection (°F)	70	76	76	68	68	62	54	51	42	36	32	32	32.5
Turbidity (Jackson)	1200	1900	1000	700.	750	1100	750	525.	660.	825	134	25.	140
Alkalinity (as $CaCO_3$) P	2.	2	-	8.0	8.0	4.0	12	4.0	6.0	3	6	5.0	2.0
Alkalinity (as $CaCO_3$) T	102.	112	106	144.	144.	142	150	158.	154.	164	224	222.	200.
pH	8.4	7.8	7.9	8.45	7.95	7.9	8.1	8.1	7.98	7.7	8.1	8.0	7.9
Calcium (Ca)	38.0	42.0	42.6	58.5	60.4	60.4	59.4	63.9	59.4	87.1	81.2	85.	68.3
Magnesium (Mg)	10.0	12.0	7.5	11.7	18.	15.7	18.3	17.5	17.0	20.9	25.9	24.3	24.5
Chloride (Cl)	10.0	16.0	15.0	18.0	18.	16.	18	17.0	13.0	17	29	30.	24.0
Sulfate (SO_4)	94.0	89.0	101.0	144.4	168.3	181.9	184.6	178.6	170.4	169.1	187.6	206.6	203.3
Silica (SiO_2)	9.0	9.0	12.5	13.5	13.	13.0	13.5	10.5	10.0	-	-	19.0	17.0
Phosphorous Soluble (PO_4)	0.30	0.18	0.23	0.26	0.21	0.26	0.36	0.20	0.19	-	-	0.30	0.50
Phosphorous Total (PO_4)	10.0	12.9	10.8	7.3	4.80	12.6	9.4	1.90	3.12	-	-	1.30	1.30
Sodium & Potassium (as Na)	40.0	39.0	43.5	61.	59.	53.4	50.4	61.7	59.7	56.5	66.8	83.7	72.
Total Organic Nitrogen (N)	6.00	7.56	3.26	2.70	0.70	2.70	0.70	0.96	0.93	1.22	0.82	0.61	1.03
Ammonia Nitrogen (N)	0.20	0.09	0.53	0.07	0.01	0.084	0.003	0.07	0.096	0.057	0.23	0.16	0.21
Nitrite Nitrogen (N)	0.008	0.007	0.011	0.005	0.020	0.052	0.002	0.007	0.025	0.041	0.0096	0.009	0.012
Nitrate Nitrogen (N)	0.30	0.71	0.44	0.3	0.19	0.62	0.73	0.57	0.61	0.60	0.62	0.62	0.48

APPENDIX E

Chemical Analyses Completed by United States Geological Survey Laboratory during October, November, December, 1950 and January 1951.

The sources of collection were as follows:

	Stations (Sample Nos.) by Month			
	October	November	December	January
Alcova Reservoir				
Alcova, Wyoming	B-13	B-18	B-32	B-47
Angostura Reservoir				
Hot Springs, S.Dakota	B-6	B-17	B-37	B-44
Bighorn River				
Manderson, Wyoming	-	-	B-41	B-57
Guernsey Reservoir				
Guernsey, Wyoming	B-5	B-29	B-36	B-45
James River				
Huron, S. Dakota	B-7	B-26	-	B-42, B-58
Missouri River				
Pierre, S. Dakota	B-9-12	B-20-23	-	B-49-52
Toston, Montana	-	-	B-38	B-43
Yankton, S. Dakota	B-1-4	B-24-27	-	B-53-55
North Platte River				
Cassa, Wyoming	B-8	B-30	B-35	B-46
Goose Egg, Wyoming	B-14	B-19	B-31	B-48
South Platte River				
Evans, Colorado	B-15	-	B-33, B-39	B-56
Littleton, Colorado	B-16	-	B-34, B-40	-

APPENDIX E(Cont.)

Summary of Chemical Samples

Submitted by U.S. Geological Survey for October 1950

No.	Source	Point of Collection	Station	Date
1	Missouri River	Yankton, S. Dakota	B-1	10-2-50
2	Missouri River	Yankton, S. Dakota	B-2	10-2-50
3	Missouri River	Yankton, S. Dakota	B-3	10-2-50
4	Missouri River	Yankton, S. Dakota	B-4	10-2-50
5	Missouri River	Pierre, S. Dakota	B-10	10-3-50
6	Missouri River	Pierre, S. Dakota	B-11	10-3-50
7	Missouri River	Pierre, S. Dakota	B-12	10-3-50
8	Missouri River	Pierre, S. Dakota	B-9	10-3-50
9	James River	Huron, S. Dakota	B-7	10-3-50
10	Angostura Reservoir	Hot Springs, S. Dakota	B-6	10-5-50
11	Alcova Reservoir	Wyoming	B-13	10-9-50
12	North Platte River	Goose Egg, Wyoming	B-14	10-9-50
13	North Platte River	Cassa, Wyoming	B-8	10-6-50
14	Guernsey Reservoir	Guernsey, Wyoming	B-5	10-6-50
15	South Platte River	Littleton, Colorado	B-16	10-13-50
16	South Platte River	Evans, Colorado	B-15	10-13-50

APPENDIX E (Cont.)
Summary of Chemical Samples

Submitted by U.S. Geological Survey for October 1950

(All results in ppm except temp., pH, spec. cond. and per cent sodium)

Station	B-1	B-2	B-3	B-4	B-10	B-11	B-12	B-9	B-7	B-6	B-13	B-14	B-8	B-5	B-16	B-15
Temperature °F	53	53	53	53	46	46	46	46	47	55	56	-	53	52	68	58
pH	7.8	7.8	7.8	7.8	7.9	7.9	7.9	7.8	7.8	7.7	7.8	8.0	8.1	7.9	8.0	7.8
Nitrite (N)	.001	.001	.001	.001	0	0	0	.001	.040	.003	0	.003	.006	.003	.006	.030
Nitrate (N)	.9	1.0	.9	.9	.50	.35	.35	.36	.15	.08	.10	.19	.46	.25	.25	1.64
Ammonia Nitrogen(N)	.03	.03	0	.01	.04	.03	.01	.04	.42	.01	.04	.05	.03	.06	.09	.29
Organic Nitrogen(N)	.23	.17	.19	.15	.44	.39	.41	.13	.49	.22	.28	.19	.22	.30	.45	.22
Total Nitrogen (N)	1.2	1.2	1.1	1.1	.98	.77	.77	.53	1.10	.31	.42	.43	.72	.61	.80	2.18
Soluble Phosphorous(P)*	.011	.012	.006	.006	.031	.028	.026	.029	.136	.008	.007	.016	.004	.007	.014	.046
Total Phosphorous(P)*	.030	.065	.080	.013	.085	.093	.084	.037	.221	.019	.056	.038	.042	.042	.022	.073
Turbidity (SiO_2)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (SiO_2)	15	15	15	12	11	11	11	12	15	10	9.8	15	14	12	15	16
Iron (Fe)	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.10	.02	.04	.04	.04
Calcium (Ca)	55	55	55	55	61	61	61	61	80	262	49	162	97	72	67	153
Magnesium (Mg)	16	16	16	16	19	19	20	20	37	51	15	40	28	22	14	81
Sodium (Na)	61	60	59	57	67	68	67	69	89	156	31	105	98	58	46	154
Potassium (K)	6.1	6.0	5.2	6.2	4.8	4.6	4.2	5.1	15	10	3.6	7.7	7.3	5.4	5.2	9.2
Bicarbonate (HCO_3)	162	162	160	161	180	180	180	180	351	172	143	208	228	186	198	320
Sulfate (SO_4)	179	177	172	174	202	204	210	214	186	900	122	560	328	204	101	715
Chloride (Cl)	10	9.0	9.0	10	10	12	11	11	48	90	10	29	26	17	45	44
Fluoride (F)	.6	.6	.6	.6	.6	.6	.6	.6	.4	.8	.4	.4	.4	.4	1.0	1.2
Nitrate (NO_3)	4.0	4.5	4.1	3.8	2.2	1.6	1.6	1.6	.7	.4	.5	.9	2.0	1.2	1.1	7.2
Boron (B)	.20	.20	.20	.20	.30	.24	.30	.20	.20	.30	.20	.30	.20	.20	.20	.30
Dissolved solids: Sum - ppm	432	428	426	432	474	474	476	490	668	1570	312	1020	728	494	392	1340
Hardness as $CaCO_3$:																
Total	204	203	202	202	229	229	233	235	353	862	184	568	359	269	225	715
Noncarbonate	71	70	71	70	81	81	85	87	65	721	67	397	172	116	83	453
Specific Conductance (Micromhos at 25°C)	634	628	630	627	702	705	709	719	985	1990	481	1360	1020	721	619	1740
Per Cent Sodium	38	38	38	37	38	39	38	38	34	28	26	28	37	31	30	32

* To express as PO_4, multiply by the factor 3.065.

APPENDIX E (Cont.)

Summary of Chemical Samples

Submitted by U.S. Geological Survey for November, 1950

No.	Source	Point of Collection	Station	Date
1	Missouri River	Yankton, S. Dakota	B-24	11-9-50
2	Missouri River	Yankton, S. Dakota	B-26	11-9-50
3	Missouri River	Yankton, S. Dakota	B-27	11-9-50
4	Missouri River	Yankton, S. Dakota	B-25	11-9-50
5	Missouri River	Pierre, S. Dakota	B-21	11-3-50
6	Missouri River	Pierre, S. Dakota	B-20	11-3-50
7	Missouri River	Pierre, S. Dakota	B-22	11-3-50
8	Missouri River	Pierre, S. Dakota	B-23	11-3-50
9	James River	Huron, S. Dakota	B-28	11-8-50
10	Angostura Reservoir	Hot Springs, S. Dakota	B-17	11-2-50
11	Alcova Reservoir	Wyoming	B-18	11-2-50
12	North Platte River	Goose Egg, Wyoming	B-19	11-2-50
13	North Platte River	Cassa, Wyoming	B-30	11-9-50
14	Guernsey Reservoir	Guernsey, Wyoming	B-29	11-9-50

APPENDIX E (Cont.)

Results of Chemical Analyses

Submitted by U.S. Geological Survey for November 1950

(All results in ppm except temp., pH, spec. cond. and per cent sodium)

Station	B-24	B-26	B-27	B-25	B-21	B-20	B-22	B-23	B-28	B-17	B-18	B-19	B-30	B-29
Temperature (°F.)	38	38	38	38	45	45	45	45	41	-	51	41	-	45
pH	8.0	8.0	8.0	8.0	8.0	7.8	8.0	7.9	8.0	7.8	7.9	7.9	8.1	8.1
Nitrite (N)	0	0	0	0	0	0	0	0	.001	.001	0	.006	.005	.005
Nitrate (N)	.30	.23	.15	.27	.20	.15	.23	.22	.08	.12	.15	.30	.25	.52
Ammonia Nitrogen (N)	.03	.02	.03	.02	.03	.03	.02	.02	.20	0	0	.01	.12	.01
Organic Nitrogen (N)	.67	.63	.50	.70	.51	.55	.58	.48	.63	.15	.15	.14	.37	.27
Total Nitrogen (N)	1.00	.88	.68	.99	.74	.73	.83	.72	.90	.27	.30	.46	.75	.81
Soluble Phosphorous(P)*	.037	.024	.023	.025	.018	.025	.018	.020	.149	.004	.008	.005	.021	.003
Total Phosphorous (P)*	1.17	1.54	1.88	1.50	.127	.100	.134	.182	.250	.039	.073	.037	.031	.028
Turbidity (SiO_2)	500	500	550	600	500	400	400	400	3	.8	7	2	4	3
Silica (SiO_2)	11	11	14	11	8.9	11	9.2	9.0	17	9.0	8.4	15	9.8	14
Iron (Fe)	.10	.02	.10	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.04
Calcium (Ca)	57	56	57	57	56	56	56	56	88	256	49	182	81	114
Magnesium (Mg)	21	21	21	21	22	22	22	22	44	65	16	51	30	42
Sodium (Na)	56	56	56	57	58	57	58	57	98	151	31	116	79	113
Potassium (K)	3.8	4.2	3.8	3.8	3.9	3.9	3.4	4.2	14	9.3	3.2	7.1	6.5	6.7
Bicarbonate (HCO_3)	183	182	183	183	184	183	182	184	387	176	145	206	215	269
Sulfate (SO_4)	180	176	174	178	177	176	183	181	215	900	120	665	275	408
Chloride (Cl)	9.5	9.0	9.5	9.0	9.0	9.0	9.0	9.0	53	89	8.0	34	20	32
Fluoride (F)	.5	.4	.1	.4	.6	.6	.6	.6	.1	.7	.3	.4	.1	.1
Nitrate (NO_3)	1.4	1.1	.7	1.2	.9	.7	1.0	1.0	.4	.5	.7	1.4	1.1	2.3
Boron (B)	.30	.30	.30	.30	.30	.30	.30	.30	.40	.30	.30	.30	.30	.30
Dissolved solids:														
Sum - ppm	434	436	442	432	448	446	452	450	742	1570	324	1170	628	928
Hardness as $CaCO_3$:														
Total	226	227	227	226	228	228	228	229	399	906	138	662	323	456
Noncarbonate	76	78	77	76	77	78	79	78	82	762	69	493	147	235
Specific Conductance (Micromhos at 25°C)	677	667	665	671	666	670	671	678	1120	2120	505	1510	927	1290
Per Cent Sodium	35	34	34	35	35	35	35	35	34	26	26	27	34	35

* To express as PO_4, multiply by the factor 3.065

APPENDIX E (Cont.)

Summary of Chemical Samples

Submitted by U.S. Geological Survey for December 1950

No.	Source	Point of Collection	Station	Date
1	Missouri River	Toston, Montana	B-38	12-7-50
2	Angostura Reservoir	Hot Springs, S. Dakota	B-37	12-8-50
33	Bighorn River	Manderson, Wyoming	B-41	12-26-50
4	Alcova Reservoir	Alcova, Wyoming	B-32	12-1-50
5	North Platte River	Goose Egg, Wyoming	B-31	12-1-50
6	North Platte River	Cassa, Wyoming	B-35	12-7-50
7	Guernsey Reservoir	Guernsey, Wyoming	B-36	12-7-50
8	South Platte River	Littleton, Colorado	B-34	12-5-50
9	South Platte River	Littleton, Colorado	B-40	12-26-50
10	South Platte River	Evans, Colorado	B-33	12-5-50
11	South Platte River	Evans, Colorado	B-39	12-26-50

APPENDIX E (Cont.)

Results of Chemical Analyses

Submitted by U.S. Geological Survey for December, 1950

(All results in ppm except temp., pH, spec. cond. and per cent sodium)

	B-38	B-37	B-41	B-32	B-31	B-35	B-36	B-34	B-40	B-33	B-39
Temperature (F°)	34	34	32	42	34	32	32	35	42	34	37
pH	7.9	7.9	8.0	7.8	8.0	7.9	8.1	7.8	8.0	7.4	7.4
Nitrite (N)	.002	.002	.002	0	.003	.010	.006	.003	0	0	.02
Nitrate (N)	.15	.09	.48	.05	.17	.93	.26	.36	.46	.12	.36
Ammonia Nitrogen (N)	.06	0	.04	.06	.01	.02	.10	.04	.02	1.21	1.53
Organic Nitrogen (N)	.17	.33	.53	.33	.24	.27	.21	.24	.25	.72	3.88
Total Nitrogen (N)	.38	.42	1.05	.44	.42	1.23	.58	.64	.72	2.05	5.79
Soluble Phosphorous (P)*	.032	.004	.005	.008	.007	.008	.017	.019	.001	.173	.022
Total Phosphorous (P)*	.060	.023	.165	.083	.048	.022	.047	.059	.010	.615	.378
Turbidity (SiO_2)	30	2	75	15	10	4	3	20	8	50	40
Silica (SiO_2)	25	9.8	4.8	6.8	15	20	11	12	11	16	13
Iron (Fe)	.08	.04	.02	.04	.04	.04	.04	.04	.02	.16	.02
Calcium (Ca)	44	285	92	52	137	146	97	59	53	147	143
Magnesium (Mg)	11	55	35	14	45	41	27	13	14	55	66
Sodium (Na)	24	149	129	31	111	130	91	40	42	141	149
Potassium (K)	5.1	9.4	3.8	5.0	7.8	8.6	6.3	3.0	3.2	20	20
Bicarbonate (HCO_3)	182	177	232	148	226	342	230	176	160	430	414
Sulfate (SO_4)	44	955	405	123	635	473	333	83	83	498	530
Chloride (Ch)	15	90	26	9.0	30	37	24	43	46	55	54
Fluoride (F)	1.2	.8	.5	.2	.4	.4	.4	1.0	.8	1.0	.8
Nitrate (NO_3)	.7	.22	.16	.3	.8	4.2	1.2	1.6	2.0	.6	1.6
Boron (B)	.10	.22	.16	.30	.18	0	0	.30	.06	.27	.17
Dissolved solids:											
Sum - ppm	272	1640	834	328	1140	1030	724	356	338	1150	1180
Hardness as $CaCO_3$:											
Total	156	936	372	186	650	534	354	201	190	594	628
Noncarbonate	7	791	182	65	465	254	165	57	59	241	289
Specific Conductance (Micromhos at 25° C)	418	2140	1200	509	1540	1450	1030	576	576	1640	1710
Per Cent Sodium	24	25	43	26	27	34	35	30	32	33	33

* To express as PO_4, multiply by the factor 3.065.

APPENDIX E (CONT.)

Summary of Chemical Samples

Submitted by U.S. Geological Survey for January 1951

No.	Source	Point of Collection	Station	Date
1	Missouri River	Yankton, S. Dakota	B-53	1-10-51
2	Missouri River	Yankton, S. Dakota	B-54	1-10-51
3	Missouri River	Yankton, S. Dakota	B-55	1-10-51
4	Missouri River	Pierre, S. Dakota	B-49	1-8-51
5	Missouri River	Pierre, S. Dakota	B-50	1-8-51
6	Missouri River	Pierre, S. Dakota	B-51	1-8-51
7	Missouri River	Pierre, S. Dakota	B-52	1-8-51
8	Missouri River	Toston, Montana	B-43	1-3-51
9	James River	Huron, S. Dakota	B-42	1-2-51
10	James River	Huron, S. Dakota	B-58	1-29-51
11	Angostura Res.	Hot Springs, S. Dakota	B-44	1-2-51
12	Bighorn River	Manderson, Wyoming	B-57	1-23-51
13	Alcova Reservoir	Alcova, Wyoming	B-47	1-4-51
14	North Platte River	Goose Egg, Wyoming	B-48	1-4-51
15	North Platte River	Cassa, Wyoming	B-46	1-3-51
16	Guernsey Reservoir	Guernsey, Wyoming	B-45	1-3-51
17	South Platte River	Evans, Colorado	B-56	1-15-51

APPENDIX E (Concluded)
Results of Chemical Analyses

Submitted by U.S. Geological Survey for January 1951
(All results in ppm except temp., pH, spec. cond. and per cent sodium)

	B-53	B-54	B-55	B-49	B-50	B-51	B-52	B-43	B-42	B-58	B-44	B-57	B-47	B-48	B-46	B-45	B-56
Temperature (°F)	33	33	33	-	-	-	-	32	-	33	-	32	36	33	33	35	36
pH	8.0	8.0	8.0	8.0	8.0	7.8	7.9	8.0	8.1	8.0	7.9	7.6	7.9	8.0	8.0	8.1	7.8
Nitrite (N)	.005	.005	.005	.003	.003	.003	.003	0	.016	.001	0	.003	.003	.004	.009	.002	.13
Nitrate (N)	.56	.64	.66	.38	.38	.33	.38	.15	.19	.20	.10	.59	.10	.47	.84	.37	1.32
Ammonia Nitrogen(N)	.07	.05	.06	.09	.03	.05	.06	.03	.96	.08	.03	.03	.06	.02	.08	.10	3.07
Organic Nitrogen(N)	.20	.26	.22	.40	.27	.40	.38	.19	.59	.96	.35	.25	.26	.28	.50	.35	.72
Total Nitrogen (N)	.84	.96	.95	.87	.68	.78	.82	.37	1.76	1.24	.48	.87	.42	.77	1.43	.82	5.24
Soluble Phosphorous(P)*	.010	.010	.011	.049	.047	.032	.022	.012	.383	.200	.005	.014	.012	.013	.009	.005	.085
Total Phosphorous(P)*	.127	.119	.094	.074	.050	.048	.049	.083	.448	.325	.052	.093	.049	.058	.037	.052	.616
Turbidity (SiO_2)	80	120	95	70	70	70	75	3	8	10	.7	15	4	4	2	2	50
Silica (SiO_2)	9.8	11	9.6	11	11	10	7.8	24	28	26	5.4	12	4.0	20	18	11	13
Iron (Fe)	.04	.02	.02	.02	.02	.02	.02	.02	.04	.02	.02	.02	.02	.06	.02	.04	.06
Calcium (Ca)	72	72	72	65	66	65	66	42	137	177	280	76	50	202	113	101	114
Magnesium (Mg)	26	25	26	24	23	26	25	12	69	75	68	29	16	57	43	35	48
Sodium (Na)	72	69	70	64	65	67	66	27	200	205	154	88	34	121	126	107	131
Potassium (K)	3.8	4.2	4.0	3.8	3.5	3.5	3.8	4.3	17	19	9.0	3.4	3.6	7.4	7.3	7.4	7.0
Bicarbonate (HCO_3)	224	226	226	212	212	212	214	178	562	696	177	212	150	254	292	247	326
Sulfate (SO_4)	230	223	230	210	205	210	218	48	430	495	1010	295	130	728	438	365	388
Chloride (Cl)	13	13	13	11	11	11	12	14	106	118	93	23	9.5	33	33	28	65
Fluoride (F)	.6	.6	.6	.5	.5	.5	.5	.9	.3	.6	.7	.4	.2	.5	.4	.4	.8
Nitrate (NO_3)	2.5	2.9	2.9	1.7	1.7	1.5	1.7	.7	.8	1.0	.4	2.6	.4	2.1	3.8	1.6	5.8
Boron (B)	-	.18	-	-	.17	-	-	.09	.45	.20	.18	.30	.02	.18	.11	.21	.15
Dissolved solids:																	
Sum-ppm	552	544	544	514	510	514	510	266	1270	1460	1710	650	328	1300	960	804	990
Hardness as $CaCO_3$:																	
Total	288	284	287	262	258	268	268	154	626	748	980	307	191	740	458	394	482
Noncarbonate	104	99	102	88	84	94	93	8	165	177	835	133	68	532	219	191	215
Specific conductance (Micromhos at 25°C)	834	830	824	787	772	781	792	426	1920	2090	2230	953	526	1720	1340	1170	1420
Per cent sodium	35	34	34	34	35	35	34	27	40	37	25	38	27	26	37	37	37

* To express as PO_4, multiply by the factor 3.065.

APPENDIX F

Chemical analyses compiled by the Nebraska State Department of Health Laboratories between June 1 and August 29, 1950.

The sampling points were as follows:

Station	Mileage Point	Geographic Location	Water Source
1A	30	Ashland, Nebraska	Platte River
2A	-	Bellvue, Nebraska	Small Creek entering Missouri River
3A	100	Columbus, Nebraska	Platte River
3B	100	Columbus, Nebraska	Platte River
3X	100	Columbus, Nebraska	Platte River
4A	369	Lewellen, Nebraska	North Platte River
4B	369	Lewellen, Nebraska	North Platte River
5A	344	Ogallala, Nebraska	Lake McConaughy
5B	344	Ogallala, Nebraska	Lake McConaughy
6A	-	Enders, Nebraska	Frenchmen Creek
6B	-	Enders, Nebraska	Frenchmen Creek
7A	-	Cambridge, Nebraska	Republican River
7B	-	Cambridge, Nebraska	Republican River

APPENDIX F (Cont.)

CHEMICAL ANALYSES FOR PLATTE RIVER, ASHLAND, NEBRASKA

Station 1A

All results in parts per million (P.P.M.)

1950	6/1	6/6	6/13	6/21	6/28	7/6	7/12	7/20	7/24	8/3	8/17	8/24
Water Temperature (°C)	19	17	24	23	20	22	23	19	22	24	-	26
pH	7.7	-	8.2	7.4	8.2	8.3	7.9	8.1	8.0	7.4	8.0	8.4
Turbidity	-	5000	370	3000	800	370	3600	5000	1500	750	2100	900
Total Alkalinity	149	-	172	140	149	149	136	130	121	152	122	136
Nitrogen Nitrate	-1	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	.003	.002	.002	.005	.001	.002	.014	.004	.003	0	.001	.008
Nitrogen Ammonia	.02	.1	.32	.50	.42	1.0	.52	.72	.38	.52	1.28	1.32
Soluble Phosphate PO_4	.222	-	.25	.308	.64	.455	.464	.272	.630	.620	.78	.69
Total phosphate PO_4	-	-	1.6	5.9	3.08	2.62	8.5	4.75	2.72	6.84	3.96	3.44
Chloride	12	10.5	8.3	8.6	10.4	12.7	7.4	4.6	6.1	12.5	3.7	4.6
Sodium	-	-	-	-	75.5	36.4	28.0	51.4	28.3	39.6	25.9	78.3
Magnesium	-	3.2	9.4	6.2	8.4	7.2	4.2	4.6	5.8	7.4	5.6	6.2
Calcium	-	80.7	99.4	87.2	81.3	64.5	102	71.6	69.1	80.2	74.0	80.5
Soluble Silica	-	-	30	54	35	54	28	18	16	36	27	36
Organic Nitrogen	-	-	-	-	-	5.0	3.5	4.8	6.0	18.2	11.0	17.4
Potassium	6	-	-	-	-	-	-	-	-	-	-	-

APPENDIX F (Cont.)

CHEMICAL ANALYSES

FOR SMALL CREEK ENTERING MISSOURI RIVER

BELLVUE, NEBRASKA - STATION 2A

All results in ppm except Temp. and pH.

	6/1/50	6/6/50	6/13/50	6/21/50	6/28/50	7/6/50	8/3/50	8/24/50
Water Temperature (°C)	22	23	27	25	25	25	24	23
pH	7.7	-	7.5	7.8	8.4	7.9	7.5	8.5
Turbidity	-	120	380	33	103	35	83	52
Total Alkalinity	312	-	342	278	310	275	288	297
Nitrogen Nitrate	-1	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	.224	.271	.155	.159	.242	.137	.220	.256
Nitrogen Ammonia	4.16	4.64	10.4	2.80	4.0	8.8	2.72	2.82
Soluble phosphate PO_4	.226	-	1.5	.94	-	4.56	.860	1.46
Total Phosphate PO_4	-	-	1.68	2.3	2.54	7.50	5.80	2.00
Chloride	26	23.8	24.4	22.0	28.2	42.3	21.9	4.6
Sodium	-	-	-	-	132	79.1	61.6	80.3
Magnesium	-	1.8	16.4	17.0	18.6	15.8	8.2	8.0
Calcium	-	38.3	99.4	87.2	102.8	81.4	90.0	115.5
Soluble Silica	-	-	13	13.5	12	14	15	20
Organic Nitrogen	-	-	-	-	-	4.5	-	9.5
Potassium	-1	-	-	-	-	-	-	-

APPENDIX F (Cont.)
CHEMICAL ANALYSES
FOR PLATTE RIVER
COLUMBUS, NEBRASKA
Station 3A

All results in ppm except temp. and pH

1950	6/1	6/6	6/13	6/21	6/28	7/6	7/12	7/20	7/24	8/3	8/18	8/25
Water Temperature (°C)	22	22	30	27	22	27	23	20	25	25	22	19
pH	8.1	-	8.1	8.0	8.1	8.0	7.9	8.1	8.2	7.9	8.2	8.3
Turbidity	-	700	-	1200	140	500	4400	4900	950	320	725	710
Total Alkalinity	143	-	143	278	124	119	110	100	117	127	109	123
Nitrogen Nitrate	-1	Tr.	Tr.	Tr.	Tr.	0	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	.016	.004	-	.021	.004	.007	.041	.007	.016	Tr.	.018	.012
Nitrogen Ammonia	.04	.32	-	.44	.39	1.04	.68	.88	.88	.44	1.48	1.98
Soluble Phosphate PO_4	.375	-	.58	.404	.456	.568	.728	.256	.660	.512	.960	.60
Total Phosphate PO_4	-	-	.6	3.3	.80	2.62	9.40	3.60	3.60	2.36	2.88	2.36
Chloride	1	4.5	6.5	6.7	2.8	7.6	5.5	3.2	5.5	5.7	1.9	2.8
Sodium	-	-	-	-	-	17.4	17.4	60.1	19.8	35.6	20.8	24.3
Magnesium	-	.2	4.7	3.6	4.4	3.8	3.6	3.0	4.8	5.2	4.2	4.8
Calcium	-	52.4	42.6	70.9	61.0	40.4	76.0	64.4	64.0	64.0	62.5	60.0
Soluble Silica	-	-	54	41	45	62	50	22	24	54	36	54
Organic Nitrogen	-	-	-	-	-	4.0	-	4.2	17.2	5.9	7.3	20.4
Potassium	-1	-	-	-	-	-	-	-	-	-	-	-

APPENDIX 2 (Cont.)

CHEMICAL ANALYSES

FOR PLATTE RIVER

Columbus, Nebraska

Station 3B

All results in p.p.m. except temp. and pH

	6/1/50	6/6/50	6/13/50
Water Temperature (°C)	21	21	30
pH	8.1	-	-
Turbidity	-	800	-
Total Alkalinity	125	-	-
Nitrogen Nitrate	-1	Tr.	Tr.
Nitrogen Nitrite	.011	.005	.001
Nitrogen Ammonia	.03	.32	2.56
Soluble Phosphate PO_4	.375	-	-
Total Phosphate PO_4	-	-	-
Chloride	3.8	4.0	-
Sodium	-	-	-
Magnesium	-	.6	-
Calcium	-	55.0	-
Soluble Silica	-	-	-
Organic Nitrogen	-	-	-
Potassium	-1	-	-

APPENDIX F (Cont.)

CHEMICAL ANALYSES

COLUMBUS, NEBRASKA - Station 3X

	6/21/50	6/28/50	7/6/50	7/12/50	7/20/50	7/24/50	8/3/50	8/18/50	8/25/50
Water Temperature (°C)	27	21	24	23	21	22	26	24	21
pH	8.0	8.1	8.1	7.9	8.1	8.4	8.0	8.1	8.3
Turbidity	2200	850	650	1800	4900	4200	230	900	680
Total Alkalinity	125	121	116	98	98	124	128	110	120
Nitrogen Nitrate	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	.011	.004	.009	.046	.008	.004	Tr.	.006	.005
Nitrogen Ammonia	.44	.42	1.02	.48	1.0	.80	.50	1.36	1.98
Soluble Phosphate PO_4	.429	.536	.492	.632	.288	.570	.456	.780	.520
Total Phosphate	6.9	2.04	2.00	4.56	4.20	6.30	1.24	2.72	3.24
Chloride	5.7	6.1	5.7	4.2	5.5	1.3	4.7	3.0	2.8
Sodium	-	10.4	14.9	23.2	52.2	43.5	37.2	29.9	10.6
Magnesium	3.3	4.2	3.9	3.8	3.6	4.0	5.0	4.2	5.0
Calcium	71.6	65.8	58.9	73.5	72.1	91.0	65.4	58.0	70.0
Soluble Silica	41	54	66	24	15	14	56	36	54
Organic Nitrogen	-	-	4.1	3.1	3.8	42.0	14.7	15.7	12.5
Potassium	-	-	-	-	-	-	-	-	-

APPENDIX F (Cont.)

CHEMICAL ANALYSES

[illegible]

LEWELLEN, NEBRASKA

Station 4A

All results in ppm except temp. and pH

1950	6/15	6/30	7/10	7/26	8/7	8/14	8/29
Water Temperature (°C)	25	-	27	22	31	29	20
pH	-	7.8	8.3	7.4	8.5	8.6	8.9
Turbidity	-	110	70	63	175	160	350
Total Alkalinity	-	214	202	214	148	228	186
Nitrogen Nitrate	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	.07	.003	.004	.002	.010	.005	.010
Nitrogen Ammonia	.20	.34	.46	.88	.60	1.08	.52
Soluble Phosphate PO_4	-	.048	Tr.	.044	.168	.032	.070
Total Phosphate PO_4	-	.33	.64	2.72	2.0	1.36	1.54
Chloride	-	29.5	29.7	26.5	13.0	18.6	17.7
Sodium	-	41.2	116.2	125.1	54.3	82.7	63.7
Magnesium	-	16.8	12.4	9.9	7.6	7.2	9.2
Calcium	-	86.6	117.5	84.6	70.3	104.1	96.0
Soluble Silica	-	20	32	17	18	35	24
Organic Nitrogen	-	-	4.6	2.5	3.8	4.9	-
Potassium	-	-	-	-	-	-	-

CHEMICAL ANALYSIS
LEWELLEN, NEBRASKA
Station 4B

All results in parts per million except turbidity and pH

	6/15/50	6/29/50	7/10/50	7/26/50	8/7/50	8/14/50	8/29/50
Water Temperature (°C)	-	-	25.5	22	28	28	19.5
pH	7.1	8.0	8.4	7.8	8.6	8.5	8.9
Turbidity	100	110	127	500	230	160	350
Total Alkalinity	231	200	179	250	228	216	184
Nitrogen Nitrate	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	-	.007	.007	.004	.006	.003	.005
Nitrogen Ammonia	-	.32	.52	.90	.56	1.02	.42
Soluble Phosphate PO_4	.124	.094	Tr.	.096	.252	.020	.053
Total Phosphate PO_4	1.17	.33	.80	6.30	2.0	1.24	2.42
Chloride	26.3	23.8	22.2	19.4	19.1	22.3	14.0
Sodium	-	96.8	83.6	101.5	114.6	104.1	62.4
Magnesium	21.2	14.4	11.4	8.5	7.4	7.6	9.2
Calcium	68.0	91.5	135	123.4	103.3	107.6	90.25
Soluble Silica	21.5	22	38	20	36	36	20
Organic Nitrogen	-	-	3.7	2.2	3.8	6.6	8.0
Potassium	-	-	-	-	-	-	-

APPENDIX F (Cont.)

CHEMICAL ANALYSES
FOR
Lake McConaughy, Nebraska
Station 5A

All results in parts per million, unless otherwise noted

	6/15/50	6/29/50	7/10/50	7/26/50	8/7/50	8/14/50
Water Temperature (°C)	24	-	23	20	26	26
pH	7.9	8.0	7.9	8.2	8.6	8.6
Turbidity *	-25	-25	-25	-25	-25	-25
Total Alkalinity	185	176	176	170	166	171
Nitrogen Nitrate	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	-	.003	.007	.005	.008	.012
Nitrogen Ammonia	-	.50	.64	.60	.64	1.04
Soluble phosphate PO_4	.156	.033	Tr.	.032	.032	.016
Total Phosphate PO_4	.45	.20	.40	4.84	.60	1.08
Chloride	21.2	24	23.0	20.0	20.6	19.5
Sodium	-	85.6	79.1	89.6	89.5	78.3
Magnesium	19.4	14.4	12.4	9.2	8.2	8.5
Calcium	52	83.0	89.0	82.6	72.8	79.5
Soluble Silica	12	10	15	12	10	9
Organic Nitrogen	-	-	4.0	6.1	6.3	5.6
Potassium	-	-	-	-	-	-

* "-25" indicates "Less than 25".

APPENDIX F (CONT.)

CHEMICAL ANALYSES
FOR
Lake McConaughy, Nebraska
Station 5D

All results in ppm except Temp. and pH

	6/29/50	7/10/50	7/26/50	8/7/50	8/14/50
Water Temperature (°C)	-	22	20	25	27
pH	7.9	7.8	8.4	8.5	8.5
Turbidity *	-25	-25	-25	-25	-25
Total Alkalinity	174	184	171	170	172
Nitrogen Nitrate	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	.005	.006	.005	.008	.012
Nitrogen Ammonia	.44	.60	.84	.96	1.14
Soluble Phosphate PO_4	.026	.22	.020	.012	.032
Total Phosphate PO_4	.48	2.72	4.20	3.24	1.56
Chloride	23.4	27.1	20.0	19.7	19.7
Sodium	83.2	74.5	86.0	107.0	74.9
Magnesium	15.0	14.4	8.5	8.0	7.8
Calcium	90.5	105.1	66.0	70.8	02.6
Soluble Silica	12	12	12	11	11
Organic Nitrogen	-	1.5	4.2	7.8	4.4
Potassium	-	-	-	-	-

* "-25" indicates "Less than 25".

APPENDIX F (Cont.)

CHEMICAL ANALYSES

FOR [illegible]

Enders, Nebraska

Station 6A

All results in ppm except temp. and pH

	6/16/50	6/30/50	7/11/50	7/27/50	8/3/50	8/15/50	8/29/50
Water Temperature (°C)	28	-	21	17	22	32.5	21
pH	-	8.0	8.0	8.4	8.6	8.6	8.9
Turbidity*	-	120	77	80	-25	125	71
Total Alkalinity	-	190	186	181	178	186	176
Nitrogen Nitrate	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	.014	.010	.010	.008	.010	.008	.009
Nitrogen Ammonia	.26	.42	.44	.52	.60	1.30	.32
Soluble phosphate PO_4	-	.062	.08	.032	.080	.032	.070
Total phosphate PO_4	-	.48	2.53	4.56	2.88	1.56	.70
Chloride	-	12.5	7.9	5.3	3.9	4.5	4.1
Sodium	-	41.5	68.6	42.3	38.5	34.6	24.6
Magnesium	-	11.2	11.4	7.3	6.6	7.1	9.4
Calcium	-	93.6	68.1	74.0	79.7	88.6	80.75
Soluble Silica	-	49	58	62.	52	56	60
Organic Nitrogen	-	-	2.4	3.2	4.2	9.2	6.2
Potassium	-	-	-	-	-	-	-

* "-25" indicates "less than 25".

APPENDIX F (Cont.)
CHEMICAL ANALYSES

For Frenchmen Creek
Enders, Nebraska
Station 6 B

All results in ppm except Temp. and pH

	6-16-50	6-30-50	7-11-50	7-27-50	8-8-50	8-15-50	8-29-50
Water Temperature (°C)	28	-	205	17	22	33	21
pH	8.0	8.0	8.0	8.4	8.6	8.4	8.8
Turbidity	110	105	78	30	124	125	64
Total Alkalinity	201	184	185	179	176	184	176
Nitrogen Nitrate	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	-	.009	.011	.008	Tr.	.008	.010
Nitrogen Ammonia	-	.41	.48	.52	.52	1.05	.36
Soluble phosphate PO_4	.200	.020	.124	.064	.048	.064	.105
Total phosphate PO_4	.79	.33	5.12	4.72	2.36	1.16	.70
Chloride	5.1	7.4	7.2	4.0	5.4	4.6	5.6
Sodium	-	27.3	34.2	-	39.8	46.7	45.1
Magnesium	15.6	11.1	12.8	7.4	6.4	7.4	8.3
Calcium	60.0	75.6	88.7	66.9	71.3	88.6	69.9
Soluble Silica	64	49	59	62	54	49	60
Organic Nitrogen	-	-	1.4	3.45	3.2	3.2	-
Potassium	-	-	-	-	-	-	-

APPENDIX F (Cont.)
CHEMICAL ANALYSES
for Republican River
Cambridge, Nebraska
Station 7A

All results in ppm except temp. and pH

	6/16/50	6/30/50	7/11/50	8/8/50	8/15/50
Water Temperature (°.)	30	-	28	25	31
pH	8.2	8.2	8.0	8.7	8.4
Turbidity	300	360	390	330	-
Total Alkalinity	242	199	193	223	174
Nitrogen Nitrate	-	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	-	.011	.010+	.008	0
Nitrogen Ammonia	-	.41	.44	.60	1.14
Soluble phosphate PO_4	.21	.272	.456	.340	.064
Total phosphate PO_4	1.56	2.20	-	3.52	1.08
Chloride	4.5	7.8	5.4	4.6	12.1
Sodium	-	45.9	137.2	29.9	63.3
Magnesium	13.0	9.8	9.8	6.2	7.4
Calcium	73	110	72.3	93.5	92.5
Soluble Silica	62.5	54	53	54	20
Organic Nitrogen	-	-	2.2	6.8	2.6
Potassium	-	-	-	-	-

APPENDIX F (Concluded)

CHEMICAL ANALYSES

for Republican River
Cambridge, Nebraska
Station 73

All results in ppm except temp. and pH

	6/16/50	6/30/50	7/11/50	7/27/50	8/8/50	8/15/50	8/29/50
Water Temperature (°C)	32	-	24	22	25	30	25.5
pH	-	8.0	7.9	8.4	8.7	8.5	8.9
Turbidity *	-	-25	-25	-25	27	-25	24
Total Alkalinity	-	211	231	196	177	178	180
Nitrogen Nitrate	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Nitrogen Nitrite	.01	.008	.014	0	.002	0	.004
Nitrogen Ammonia	.22	.50	.60	.64	.60	1.12	.40
Soluble phosphate PO_4	-	.020	.344	.140	.108	.032	.184
Total phosphate PO_4	-	.20	5.12	4.00	2.20	.80	1.18
Chloride	-	6.3	8.9	5.3	4.6	4.6	4.3
Sodium	-	36.6	72.2	35.6	14.9	35.4	29.2
Magnesium	-	9.3	11.4	7.8	6.8	8.2	9.0
Calcium	-	81.1	84.2	66.4	80.1	79.6	57.6
Soluble Silica	-	26	32	28	17	15	16
Organic Nitrogen	-	-	9	-	5.0	2.95	4.2
Potassium	-	-	-	-	-	-	-

* "-25" indicates "Less than 25".